Final Report

Montana Department of Natural Resources & Conservation

State Trust Lands Sustainable Yield Calculation

Prepared by:

Henk Stander
Mark Rasmussen
Brian Long
Brandon Vickery
Jessica Burton-Desrocher

Mason, Bruce, & Girard, Inc.
707 SW Washington Street, Suite 1300
Portland, Oregon 97205

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MB&G

Natural Resource Consultants Since 1921

Final Report

Montana Department of Natural Resources & Conservation:

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List of Acronyms

ARM: Administrative Rules of Montana. Agency regulations, standards or statements of applicability that implement, interpret, or set law or policy. DNRC has adopted ARMs that address Forest Management on forested state trust lands.

BA: Basal Area. The area, expressed in square feet, of the bole of the trees on an acre at breast height.

BBF: Billion Board Feet. A unit of measure for timber volume expressed in billions of board feet.

BDL Forestry: A forestry consultancy owned by Brian Long, who is a past employee of the DNRC and contributor to previous sustainable yield calculations. BDL Forestry provided critical support in establishing the starting point inventory for this calculation, as well as assistance and local expertise in calibrating the growth and yield models.

CCRX: Clear-Cut Management Prescription. An aggregate term for even-aged management pathways (EARX) that terminate in a regeneration harvest, which leaves 4 trees per acre (leave trees) as an over-story contribution towards the regenerated stand. These leave trees are not reduced with a second entry harvest.

CE: Central Land Office. A DNRC administrative office that includes all the administrative units from the central part of Montana. Units included in the Central Land Office are Bozeman (BOZ), Conrad (CON), Dillon (DIL) and Helena (HEL).

CT: Commercial Thinning. A silvicultural treatment incorporated into even-aged management pathways (EARX), which calls for a partial harvest that reduces the trees per acre down to a predetermined threshold. Volume removed is considered commercial since harvest is scheduled at an age which should produce merchantable trees. The purpose of this treatment is to reduce the competition between trees for resources, allowing the retained trees to potentially accelerate growth.

DBH: Diameter at Breast Height. A measure of the diameter of a tree at 4.5 feet above ground level (breast height).

DNRC: Department of Natural Resources and Conservation. The state agency tasked with managing the Montana trust lands to create revenue for the beneficiaries, while considering environmental factors and protecting the future income-generating capacity of the land.

EA: Eastern Land Offices. A collective term for the land offices and administrative units from the eastern part of Montana. Land offices included are Southern, Northeastern and Eastern. Units included are Billings (BIL), Glasgow (GLA), Havre (HAV), Lewistown (LEW) and Miles City (MIL).

EM: Eastern Montana. A term used in reference to the Forest Vegetation Simulator (FVS) variant for the eastern parts of Montana (Central and Eastern Land Offices).

EARX: Even-Aged Management Prescription. An aggregate term for management pathways terminating in a regeneration harvest, during which the majority of trees are removed, resulting in a single-age regenerated stand (single canopy structure). Some of these pathways include options to do pre-commercial and commercial thinning.

FIA: United States Forest Service Forest Inventory and Analysis. A program of the United States Forest Service, tasked with running a continuous national census on forest land, and predicting the future state of forests.

FVS: Forest Vegetation Simulator. A growth and yield simulator developed by the United States Forest Service for predicting the future forest conditions. It was used in the 2015 sustainable yield calculation to predict the future yields from DNRC lands under various management pathways.

GIS: Geographic Information System. A computerized system for storing and analyzing geographic data. GIS was used extensively in the 2015 sustainable yield calculation to establish the location of stands for growth modeling, as well as their participation in various wildlife and habitat constraints.

GORX: Grow-Only Management Prescription. A management pathway with no active management anywhere along the planning horizon (i.e. no regeneration harvest, thinning, or selection harvest).

GZB: Grizzly Bear. A term commonly used in this report, which refers to various habitat constraints applied that mitigate adverse effects to grizzly bears.

HCP: Habitat Conservation Plan. A 50 year plan prepared under the Federal Endangered Species Act to conserve threatened and endangered species. In developing the plan DNRC worked cooperatively with the United State Fish and Wildlife Service to adopt habitat mitigation and measures within its forest management that minimize and mitigate forest management impacts on 5 terrestrial and aquatic species including grizzly bear, Canada lynx, bull trout, west-slope cutthroat and Columbia red-band trout.

IE: Inland Empire. A term used in reference to the Forest Vegetation Simulator (FVS) variant for the western parts of Montana (Northwestern and Southwestern Land Offices).

LMA: Lynx Management Area. A key geographic area in the context of DNRC ownership that is of notable importance for lynx. LMAs are delineated zones that contain forested trust lands where increased levels of lynx conservation commitments are applied. Within these areas, records indicate that lynx are likely present (or have been in the relatively recent past) or lands are considered important for maintenance of resident lynx populations.

LP: Linear Programming. A mathematical programming technique used to solve problems that contain a series of linear equations, which can be subdivided into an objective function that needs to be optimized, and a set of constraints that limits the extent of the optimization.

MB&G Mason, Bruce & Girard. A natural resource management consultancy based in Portland, OR which was hired by the DNRC to perform the 2015 sustainable yield calculation.

MCA: Montana Code Annotated. Codification and compilation of existing Montana state general and permanent law.

MBF: Thousand Board Feet. A unit of measure for timber volume expressed in thousands of board feet.

MMBF: Million Board Feet. A unit of measure for timber volume expressed in millions of board feet.

NW: Northwestern Land Office. A DNRC regional administrative office that includes all the administrative units from the north-western part of Montana. Units included in the Northwestern Land Office are Kalispell (KAL), Libby (LIB), Plains (PLN), Stillwater (STW) and Swan (SWN).

NDY: Non-Declining Yield. A term used in context of harvest scheduling and controlling the period-on-period difference in harvest volumes, where the volume for each planning period is allowed to increase from one period to the next, but not decrease.

OGRX: Old-Growth Management Prescription. An aggregate term for all old-growth management pathways that include a selection harvest (partial harvest). Harvests occur on a periodic basis (30 or 50 years) and trees are selected for harvest based on a basal area target for the stand as a whole, as well as a trees per acre target for large trees (large defined by a DBH threshold). The objective of these management pathways is to allow selection harvest from old-growth stands, while maintaining their old-growth status.

OS: Over-Story. The trees that are kept after the regeneration harvest on even-aged management pathways (EARX) for the purposes of aiding the regeneration of the next stand of trees. The composition of the over-story is dependent on the even-aged management objective (CCRX, STRX, or SWRX), as well as the timing and intensity of removal during the second entry harvest.

PCT: Pre-Commercial Thinning. A silvicultural treatment incorporated into even-aged (EARX) and uneven-aged (UERX) management pathways, which calls for a partial harvest that reduces the trees per acre down to a predetermined threshold. Volume removed is considered pre-commercial since harvest is scheduled at an age which should not produce merchantable trees. The purpose of this treatment is to reduce the competition between trees for resources, allowing the retained trees to potentially accelerate growth.

QMD: Quadratic Mean Diameter. A measure of the diameter at breast-height for the tree of average basal area in a sample of trees.

RMZ: Riparian Management Zone. Under the DNRC HCP and Forest Management Administrative Rules (ARMs 36.11.401 through 36.11.450), an RMZ refers to streamside buffer established when forest management activities are proposed on sites with high erosion risk or on sites that are adjacent to fish-bearing streams or lakes (ARM 36.11.425).

SB: Senate Bill. A proposed or passed piece of legislation that is introduced to the legislative process through the Montana Senate.

SDI: Stand Density Index. A measure of tree stocking, expressing the degree to which trees are utilizing the available growing space. Calculation is based on the number of trees and the diameter at breast height of the tree with average basal area.

SFLMP: State Forest Land Management Plan. A programmatic plan adopted by DNRC in 1996 that provides the philosophical basis and technical rationale for DNRC's forest management program on state trust lands. The resource management standards contained in the selected alternative were adopted into administrative rules in 2003.

SLI: Stand Level Inventory. The DNRC's central repository for all stand register data. Each record in this database represents a single stand, with a stand defined as a piece of land that is uniform with regards to the properties of its vegetation, and is identified through a known stand boundary. These stand boundaries are contained within the agency's Geographic Information System (GIS), which is fully integrated with the SLI.

STRX: Seed-Tree Management Prescription. An aggregate term for even-aged management pathways (EARX) that terminate in a regeneration harvest, which leaves 8 trees per acre (leave trees) as an over-story contribution towards the regenerated stand. These leave trees are reduced to 4 trees per acre with a second entry harvest, 10 years after the regeneration harvest.

SW: Southwestern Land Office. A DNRC regional administrative office that includes all the administrative units from the south-western part of Montana. Units included in the Southwestern Land Office are Anaconda (ANA), Clearwater (CLW), Hamilton (HAM), and Missoula (MSO).

SYC: Sustainable Yield Calculation. The calculation of the harvest volume that can be sustained over the planning horizon, given the projected stand yields and habitat constraints, and an inventory of standing trees in the final planning period that can theoretically sustain the same harvest volumes beyond the planning horizon.

SWRX: Shelter-Wood Management Prescription. An aggregate term for even-aged management pathways (EARX) that terminate in a regeneration harvest, which leaves 30 trees per acre (leave trees) as an over-story contribution towards the regenerated stand. These leave trees are reduced to 4 trees per acre with a second entry harvest, 20 years after the regeneration harvest.

TPA: Stems per Acre. The estimated count of trees (stems) on one acre of land.

UERX: Uneven-Aged Management Prescription. An aggregate term for management pathways that include a selection harvest (partial harvest). Such harvests occur on a periodic basis (30 or 40 years) and trees are selected for harvest based on a pre-determined DBH distribution. This distribution is an abstraction of what a multi-aged stand (heterogeneous canopy structure) would look like, and trees are selected for harvest in such a manner as to move the stand closer to this distribution. Some of these pathways include options to do pre-commercial and commercial thinning.

UMZ: Unique Management Zone. Land parcels with unique management considerations, due to their inclusion in Conservation Agreements & Easements, as well as Federal Wild & Scenic River Corridors.

USFS: United States Forest Service. The agency of the U.S. Department of Agriculture charged with managing the national forests.

List of Technical Terms

Commercial Forest Land: Timber land capable of growing commercial crops of trees. Land that can grow 20 cubic feet of timber volume per acre per year.

Cruise: To take field measurements of trees in a timber stand. Cruising is a statistical sampling technique.

Deferred Land: Timber land not managed for timber production due to other administrative uses, topography and/or other physical factors, accessibility problems, or high development costs relative to timber values.

Even-Aged Management: A management regime culminating in a final harvest. Trees in the newly regenerated stand will be of a similar age.

Even-flow: A term used in context of harvest scheduling and controlling the period-on-period difference in harvest volumes, where the volume for each planning period has to be exactly the same.

Grizzly Bear Core: Areas within the DNRC Stillwater Unit intended to provide security for grizzly bears, which meet the Interagency Grizzly Bear Committee definition of "Core." For this calculation, the total core area was based on the existing condition in 2004 as described in the DNRC Habitat Conservation Plan environmental analysis. Constraints were required to be re-applied to these lands following a court order issued on August 21, 2014, which formed the basis for one of the alternative runs addressed in this report. Of the total core area in 2004, a subset of 34,363 commercial acres were identified and deferred from harvest.

Grizzly Bear Security Zones: Areas within the DNRC Stillwater Unit intended to provide security for grizzly bears, which generally meet the Interagency Grizzly Bear Committee definition of "Core." For this calculation, the Security Zone Areas were based on land areas identified in a negotiated settlement (August 20, 2015) between DNRC and Plaintiffs in a lawsuit involving the DNRC Forest Management Habitat Conservation Plan. Of the 22,007 acres of security zones identified in the settlement agreement, 21,966 commercial acres were identified and deferred from harvest.

Land Board: The State Board of Land Commissioners consists of Montana's five top elected officials who direct the management of State trust lands administered by the Department of Natural Resources and Conservation.

Maximum Biological Potential: The highest level of timber harvest that could be sustained, assuming all commercial timber land is available for harvest, and optimal management regimes could be implemented. This is a measure used to benchmark the productivity of a forest.

Management Regime: A schedule of specific management actions to be applied to a timber stand over time. Management actions may include activities such as natural regeneration, pre-commercial thinning, commercial thinning, regeneration harvest, selection harvest, etc.

Old Growth: A timber stand is designated as "old growth" if it meets the old-growth minimum criteria found in Green *et al*. (1992) as adopted by the DNRC.

Planning Horizon: The number of years, or planning periods, for which a strategic planning effort makes future predictions.

Second Entry Harvest: The second harvest associated with even-aged management pathways (EARX), where the over-story of trees kept after the regeneration (first) harvest is reduced down to the final number of trees per acre.

Sustainable Yield: "…the quantity of timber that can be harvested from forested state lands each year in accordance with all applicable state and federal laws, including but not limited to the laws pertaining to wildlife, recreation, and maintenance of watersheds, and in compliance with water quality standards that protect fisheries and aquatic life and that are adopted under the provisions of Title 75, chapter 5, taking into account the ability of state forests to generate replacement tree growth." (MCA 77-5-221)

Tariff Equations: Equations that the DNRC uses to calculate Scribner board foot volumes for a tree, given the species, height and DBH of the tree.

Timber Stand: A tract of forest land relatively homogenous with respect to species mix, size and stocking of tree species. The minimum stand size is five acres.

Timber Type: A code assigned to each timber stand describing the existing species mix, size class and stocking class.

1 Acknowledgements

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Finally, we acknowledge the contributions of Dave Mason, founder of our firm in 1921. His early and zealous advocacy for sustainable forest management practices have had long lasting impacts on how our society views and manages our forest resources.

2 Executive Summary

The Trust Land Management Division of the Montana Department of Natural Resources (DNRC) manages approximately 730,000 commercial forest acres for the benefit of the Common Schools and other endowed institutions. Management activities on those lands focus on providing a consistent and long-term revenue source for the trust beneficiaries, which is generated by selling a consistent annual timber volume. The amount of timber sold annually is determined through a sustainable yield calculation (MCA 77-5-223).

The last sustainable yield calculation was performed in 2011 in conjunction with the DNRC's development of a Habitat Conservation Plan for five terrestrial and aquatic species, and set a sustainable harvest level of 57.6 million board feet (MMBF) annually.

Since that last calculation in 2011, DNRC has acquired ±67,000 acres of former industry-owned timber land. That acquisition was the catalyst for a bill (SB 154) in the 2013 Montana legislative session requiring the DNRC to conduct a new calculation beginning on July 1, 2013. Pursuant to state law (MCA 77-5-222), requiring that an independent third party conduct the calculation, the DNRC contracted with Mason, Bruce & Girard in 2014 to perform the calculation.

For this sustainable yield calculation, and in contrast to prior calculations, the DNRC relied heavily on data collected from its own lands, resulting in a significant improvement in inventory estimates and growth and yield projections. For this calculation the DNRC also emphasized using the professional expertise of its field staff for several facets of the project, including updating areas deferred from active management, identifying lands suitable for helicopter logging, designing management regimes, and verifying growth and yield projections. The DNRC also used the Inland Empire and Eastern Montana variants of the Forest Vegetation Simulator, both of which are specific to Montana forests, for growth and yield projections. Data used for this calculation also accounts for the impacts of damaging agents, including wildfires and insect outbreaks that have affected over 105,000 acres of forested trust lands since 2004.

For this calculation, MB&G evaluated four scenarios. The first two scenarios addressed uncertainty at the time of project initiation regarding management of the Grizzly Bear Core in the Stillwater Unit due to litigation in U.S District Court involving DNRC's Habitat Conservation Plan. For the first scenario, the Grizzly Bear Core, which includes a total of 38,470 acres, was made available for management, resulting in an annual sustainable harvest level of 57.8 MMBF. For the second scenario, management in the Grizzly Bear Core was restricted, resulting in an annual sustainable harvest level of 55.5 MMBF.

The third scenario incorporated the terms of the settlement agreement reached between the plaintiffs and DNRC in a U.S. District Court case regarding management of grizzly bear habitat in the Stillwater Unit. For this scenario, management was restricted in 22,007 total acres of the Stillwater Unit designated as Grizzly Bear Security Zones, resulting in an annual sustainable harvest level of 56.9 MMBF. As of publication of the Final 2015 Sustainable Yield Calculation, the settlement agreement is proceeding through the U.S. District Court of Montana and has not yet been formally approved by the Court. Upon District Court approval of the settlement agreement, DNRC would implement this scenario.

The fourth scenario evaluated was designed to determine the impact of the ±67,000 recently acquired acres on the sustainable yield. For that scenario, the acquired lands were withdrawn from the model developed for the first scenario where Stillwater Unit Grizzly Bear Core was available for management, resulting in an annual sustainable harvest level of 53.2 MMBF and inferring that the addition of those lands contributes 4.6 MMBF to the annual sustainable yield.

For all scenarios, acres identified as suitable only for helicopter logging did not contribute to the annual sustainable yield and were considered to provide an opportunistic amount of volume above and beyond the calculated yields when markets permit. When market conditions are feasible for helicopter logging, those lands could contribute an additional 1.1 MMBF to the annual sustainable yield.

Although the results of this calculation are similar to previous calculations, there are important factors that distinguish this effort from past efforts and that provide a significant contribution to these results. The acquired lands contribute an additional 4.6 MMBF of volume to the annual sustainable harvest per year; however, this was largely offset by reductions in inventory due to the effects of wildfires and insect outbreaks on over 105,000 acres forested trust lands, particularly in the Southwestern, Central, and Eastern areas since 2004 that were not accounted for in the 2011 calculation. Additionally, this calculation represents a significant step forward for DNRC in terms of data quality that is reflected in the results of the calculation.

3 Purpose, Need and History

3.1 Purpose of and Need for the Sustainable Yield Calculation

The Trust Land Management Division of the Montana Department of Natural Resources and Conservation (DNRC) Forest Management Program manages approximately 780,000 forested acres for the benefit of the Common Schools and other endowed institutions. Of those 780,000 acres, approximately 730,000 acres are commercial forest land. Commercial forest land includes those lands that are dominated by commercial conifer species and have potential productivity greater than 20 cubic feet/acre/year. DNRC manages trust lands to "produce revenues for the trust beneficiaries while considering environmental factors and protecting the future income-generating capacity of the land."[1]

On forested trust lands, the DNRC's management standards and philosophy are guided by the State Forest Land Management Plan (SFLMP)[2], associated Administrative Rules (ARM)[3] and the DNRC's Forested State Trust Lands Habitat Conservation Plan (HCP)[4]. Management is based on maintaining biodiversity and sustainability, while utilizing active forest management[5]. Annual activities on forested state trust lands are aimed at generating income, monitoring and improving practices, investing in the future productivity of forested stands, and conserving an array of resources.

Revenue from forested state trust lands is primarily derived from the sale of forest products. State law directs the DNRC to sell a consistent amount of timber each year, as determined by the annual sustainable yield calculation, which in turn provides a consistent revenue source for the trust beneficiaries.[6] State law also requires that the DNRC, under the direction of the State Board of Land Commissioners (Land Board), commission an independent third party to calculate the annual sustainable yield for forested state trust lands at least once every 10 years.[7] Annual sustainable yield is defined as:

"…the quantity of timber that can be harvested from forested state lands each year in accordance with all applicable state and federal laws, including but not limited to the laws pertaining to wildlife, recreation, and maintenance of watersheds, and in compliance with water quality standards that protect fisheries and aquatic life and that are adopted under the

[1] Mission Statement, Trust Lands Management Division, Montana Department of Natural Resources
[2] Montana DNRC, State Forest Land Management Plan, 1996
[3] Administrative Rules of Montana for Forest Management, 2003
[4] Montana DNRC, Forested State Trust Lands Habitat Conservation Plan Record of Decision, December 2011.
[5] Montana DNRC, Trust Lands Management Division Annual Report FY 2014
[6] Montana Code Annotated (MCA) 77-5-223
[7] MCA 77-5-222

provisions of Title 75, chapter 5, taking into account the ability of state forests to generate replacement tree growth."[8]

Periodic recalculation of sustainable yield is necessary to incorporate changes in management intensity or emphasis, or as new laws and regulations are applied.

In 2013, MCA 77-5-222 (Appendix G: Summary of SYC Law from Montana Code Annotated) was amended as a result of the passage of Senate Bill 154, directing the Department to conduct a new study to determine the annual sustainable yield on forested state lands effective July 1, 2013, as a result of acquiring approximately 67,000 acres of former industry-owned timber land.

In 2014, the DNRC contracted with Mason, Bruce & Girard, Inc. (MB&G) to perform the sustainable yield calculation. Established in 1921, MB&G is a natural resources consulting firm located in Portland, Oregon. MB&G has performed similar calculations for a variety of federal, state, private and tribal landowners across the US. MB&G performed the DNRC's previous two sustainable yield calculations in 2004 and 2011, as well as the Montana Department of Fish, Wildlife, and Parks' 2013 Forest Inventory and Sustainable Yield Calculation.

3.2 History

3.2.1 Past Sustainable Yield Calculations

DNRC has calculated a sustainable yield four times in the past 35 years, as shown in Table 1.

Table 1: Past Sustainable Yield Calculations

Year	Sustainable Yield Calculation	Acres Included In The Calculation
1983[9]	50.0 MMBF	399,700
1996[10]	42.2 MMBF	363,769
2004[11]	53.2 MMBF	430,784
2011[12]	57.6 MMBF	469,159

The last sustainable yield calculation was completed in December 2011 by MB&G in conjunction with DNRC's development of a HCP for five terrestrial and aquatic species. That study determined that the annual sustainable harvest level was 57.6 MMBF.[13]

[8] MCA 77-5-221

[9] Sheartl, Dick, Montana Department of Natural Resources, Allowable Cut Report, August 26, 1983

[10] Arney, James D., The Annual Sustained Yield of Montana's Forested State Lands, December 1996.

[11] Mason, Bruce & Girard, 2004 Sustained Yield Calculation, State of Montana Department of Natural Resources, November 20, 2004.

[12] Montana DNRC, Forested State Trust Lands Habitat Conservation Plan Record of Decision, December 2011.

[13] MBF – thousand board feet; MMBF – million board feet; BBF – Billion board feet, all in Scribner measure. A typical log truck holds 4-5 MBF.

From FY 1997 through FY 2003, the DNRC based the timber sale program on the 1996 calculation. In 2003, the Legislature directed the DNRC to sell 50 MMBF annually.[14] In 2004, the annual sustainable yield was calculated to be 53.2 MMBF; this calculation also served as the baseline for the no-action alternative for DNRC's HCP. The DNRC based its annual timber sale requirement on the 2004 calculation until 2012 when its HCP was adopted, increasing the annual sustainable yield to 57.6 MMBF.

The annual timber sale program since 1997 is shown in Figure 1.[15] In some years, sold volumes exceeded the basis provided by the sustainable yield calculation due to timber salvage activities following wildfires or insect infestations that required timely entry to capture the value of the standing dead timber, or less frequently due to resale of unsold volume that was offered for sale in prior years.

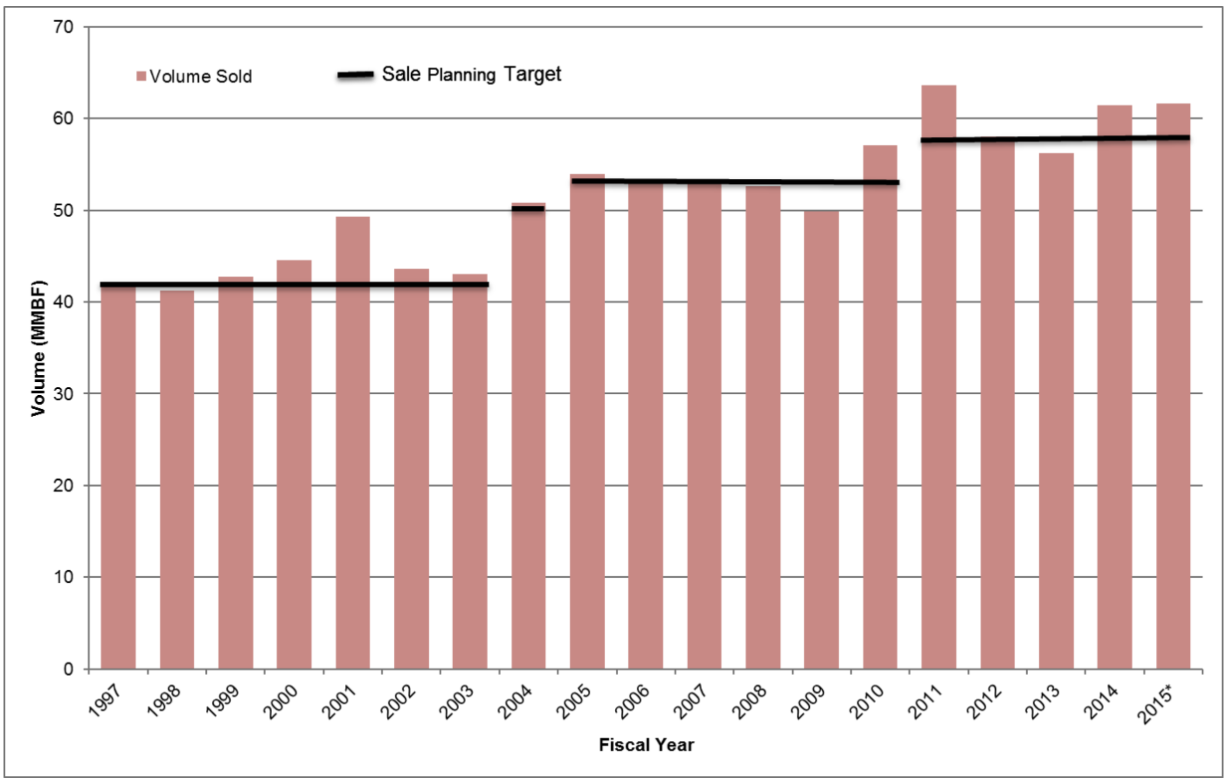

Figure 1: Volume sold from State Lands, FY 1997-2015 (MMBF, saw timber)

3.2.2 Changes since the 2004 and 2011 Sustainable Yield Calculations

In the report for the 2004 calculation, MB&G made several recommendations to the DNRC to improve on the efforts made for that calculation as well as previous efforts. Foremost among

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[14] 77-5-222 MCA, 2003

[15] Note that Figure 1shows volume sold, not volume harvested. While revenues ultimately flow to the beneficiaries based on harvest, the volume sold is a more direct measure of DNRC annual timber sale effort. Volume sold for FY 2015 is estimated.

those recommendations were to collect more plot data from stands representative of those managed by the DNRC, and to keep its inventory database, the Stand Level Inventory (SLI), current.

In response to those recommendations and to produce improved results over prior sustainable yield calculation efforts for this calculation, DNRC initiated several steps to increase its understanding of conditions on and affecting forested state trust lands, as well as the quality of its data:

- Many widely-used forest growth and yield models require tree-level data for operation, including the chosen forest growth and yield model for the 2004 and 2011 sustainable yield calculations. Such data was not available from DNRC-managed stands at the times of those calculations, requiring that tree-level data from other sources—that did not necessarily reflect the types of sites and management implemented on DNRC-managed lands—be used for those efforts. To address that issue and strengthen the result of this calculation, DNRC undertook a major effort in 2014 to collect plot data directly from its forested lands in the Central, Northwestern, and Southwestern Land Offices. Tree-level data were collected from over 5,300 plots in over 300 stands across those areas, including data on species, diameter, height, crown ratio, defect, growth rates, and mortality. This data has facilitated a better understanding and representation of forested conditions on much of DNRC's forested trust lands.
- DNRC has kept its SLI current through quarterly updates each year. Updates are based on harvest activities or on re-visitation of individual stands. DNRC also has used contracted services to provide updated stand walk-through data for several administrative Units, and has also used photo-interpreted data to update stands that have not had direct visitation through walk-through data collection.
- DNRC undertook measures to update several other data sources, including road and hydrology GIS layers, which resulted in a more accurate representation of the amount and location of those features and their impacts on management.
- DNRC used an ArcGIS online project with its foresters to review and reclassify stands that are deferred from management. For this exercise, DNRC reviewed and revised stand deferral criteria, resulting in a more accurate representation of stands that are not currently available for management due to factors including topography, wet areas, low productivity, low timber value combined with high development costs, inaccessibility, timber conservation licenses, and other land uses, among others.
- DNRC used an ArcGIS online project to identify ground suitable for helicopter yarding. This allowed DNRC to more accurately depict stands that would be available for management when market conditions make harvesting with helicopter systems feasible.

Other notable changes since the previous calculations in 2004 and 2011 include events that caused substantial amounts of tree mortality on state trust lands, such as wildfires, insect & disease outbreaks, and the acquisition of former industry-owned timberlands. The effects from fires and insect & disease outbreaks that occurred between 2004 and 2011 were not included in the 2011 calculation.

Since 2004, several large wildfires have impacted forested trust lands, particularly in 2007 when several fires prompted a widespread salvage harvesting effort to capture the value of dead trees and expedite rehabilitation and regeneration of those forests. Some notable fires that have impacted forested trust lands since 2004 include the Black Cat, I-90, Mile Marker 124, and West Mullan fires on the Missoula Unit, the Jocko Lakes fire on the Clearwater Unit, the Pine Ridge Complex on the Eastern Land Office, the Firestone Flats fire on the Kalispell Unit, the Chippy Creek fire on the Plains Unit, and the Dahl and Derby fires on the Southern Land Office. Approximately 23,200 acres of commercial forested trust lands have burned since 2004, and the DNRC conducted salvage timber harvesting on over 8,700 acres, removing over 31.5 MMBF of timber.

Insect and disease outbreaks have also significantly impacted forested trust lands since 2004. A statewide mountain pine beetle outbreak had widespread impacts in DNRC's Anaconda, Bozeman, Clearwater, Dillon, Helena, and Missoula Units, as wells as portions of the Southern Land Office. Approximately 81,570 acres of forested trust lands were affected by the mountain pine beetle outbreak between 2004 and 2014. Other insects, such as western spruce budworm, have widely infested Douglas-fir and spruce-fir stands, in some cases causing tree mortality following repeated defoliation, and in all cases reducing growth and vigor of infested standing live trees. In response to those outbreaks and infestations, DNRC conducted salvage harvesting on 19,728 acres, removing 83.8 MMBF of timber, to recover the value of the dead trees, reduce fire hazard, and regenerate stands.

DNRC has also acquired approximately 67,000 acres of former industry-owned timber land, primarily in the Missoula, Clearwater, and Swan Units. Much of this land was heavily managed in the past and is now stocked to varying degrees with seedling/sapling and pole timber stands that will not produce appreciable harvest volume for several decades.

3.3 Uses & Limitations

This sustainable yield calculation is based on a great deal of spatial and tabular data about the forest. Some of the data are site specific, other data are more generalized. A Forest Management Model was designed to address strategic level questions.[16] Specifically, the model was designed to provide a reasonable and defensible estimate of:

[16] Strategic questions: How should we manage this forest to meet objectives? What kinds of management regimes are most compatible with our objectives? How important are current investments for meeting future harvest objectives?
Tactical questions: Which roads should we build and which stands should we harvest first?
Operational questions: Where should the landing go?

- A sustainable harvest level from DNRC lands, along with associated revenues;
- The interaction between management, and wildlife habitat and water resource constraints; and
- A projection of forest conditions across DNRC lands.

Given the data and effort invested in the modeling effort, it may be tempting to try to use the model for purposes beyond the stated objectives. As discussed below, however, the model has limited spatial capabilities. Readers are cautioned against trying to use the model for more tactical, operational or site-specific tasks. While the model might be used to analyze general management strategies, for example, it should not be used to locate harvests into specific stands or under specific management regimes.

4 Data and Methods

This section will discuss the various data sources used for the 2015 SYC, as well as the analytical methods that were used to convert raw data into usable information. The discussion will start with a general overview of the modeling approach to describe the main components of the model and how they relate to each other. This will be followed by a more detailed discussion of these components, with emphasis on describing the land information used, how this was compiled into an inventory estimate, followed by growth predictions, and concluding with an optimization of the sustainable yield calculation.

4.1 Overview of the Forest Management Model

The objective of the forest management model that was developed for the 2015 SYC was to find the optimum sustainable harvest for the land managed by the DNRC, subject to fulfilling the agency's obligations towards wildlife habitat, water resources, managing the land towards a desired future condition, and the operational constraints inherent to the organization. In order to answer this question the appropriate data is required, as well as an analytical routine capable of processing the data into a solution. With regards to data, projections of future stand conditions are required, and to obtain these, a series of analytical steps needs to be followed. Estimating yield projections therefore begins with a description of the existing condition of the land, which is derived through an inventory process using a combination of land data and tree measurements. This results in a set of stand tables, but these tables are rarely sufficient to describe all of the land, so a process of stratification is used to generalize the available data across all the land. Once the stratified stand tables are available, then the yield projection process can start, which essentially is a series of analytical steps aimed at predicting future growth. While predicting this future growth, the concept of management options is introduced into the modeling framework. The purpose of presenting multiple management pathways is twofold. First, it generates options for maximizing yield by allowing the model to select the pathway that attains the stated goals in the most efficient way possible. Second, it introduces flexibility into the model, allowing it to change course in order to remain feasible with regards to constraints. The final step in this modeling framework is therefore to take these yield predictions and incorporate them into an optimization model together with a description of the land, a set of rules describing the allowable actions that can be taken, a set of desired outcomes, and an objective for optimization. Together, these elements form the optimization model, which will be solved to find the maximum sustainable harvest level, subject to meeting wildlife, water resources and operational constraints.

The details of the data and methods used in this analysis will be discussed in detail below. In short, the modeling effort consisted of combining the cruise and SLI data through a stratification process into an inventory estimate, which described the current state of the land. The data from this process was used in the Forest Vegetation Simulator (FVS) in conjunction with management pathways to make future yield projections. These projections were used within a LP modeling framework to optimize the sustainable harvest level subject to meeting wildlife, water resource, and operational constraints.

4.2 Land Base

The description of the land base is a fundamental part of the modeling framework, since it provides estimates of size (how many acres), content (what is on these acres) and location (where is it). As such, the land base data plays a pivotal role in stratification, inventory calculation, management pathway allocation and setting the starting condition for the LP optimization model. Within the DNRC Forest Management Program, the Stand Level Inventory (SLI) is the central repository for all land data and as such it merits further discussion.

4.2.1 The Stand Level Inventory (SLI)

The DNRC's Stand Level Inventory is the central repository for all of the agency's stand register data. Each record in this database represents a single stand, with a stand defined as a piece of land that is uniform with regards to the properties of its vegetation, and is identified through a known stand boundary. These stand boundaries are contained within the agency's Geographic Information System (GIS), which is fully integrated with the SLI.

In total, the SLI contains approximately 35,000 stand records, of which approximately 27,000 is commercial forested land. A number of attributes are contained within these records, each describing a different aspect of the stand. Of these, the following attributes were essential to this modeling effort:

Table 2: List of Key SLI Parameters

Land Office	The land office to which the stand belongs
Unit	The administrative unit, within a land office boundary, to which the stand belongs
Species	A description of timber type, in terms of major species
Size	The existing dominant tree (timber) size
Stocking	The density of trees in the stand
Age	An estimated average age for the stand
Productivity	The expected average productivity in terms of ft^3/acre/year
Habitat Type	The stand's habitat type classification
Acres	The net acres contained within the stand

SLI data is typically gathered by "walk-through" or photo interpretation data gathering. The SLI database used in this analysis was current as of September 2014.

4.2.2 *Other Information about the Timberland Base*

Various GIS layers were used while preparing data for this modeling effort. These layers were primarily used to incorporate various wildlife habitat and operability considerations into the model, by flagging land parcels that were inside and outside of these areas. The following data elements were therefore incorporated into the model through a series of GIS overlay analyses:

Table 3: Additional Timberland Information

Deferred	Acres deferred from management, due to operational issues such as, legal access, topography, excessively wet areas, and cabin site leases.
Riparian Management Zone (RMZ)	"No harvest" zones established immediately adjacent to Class 1 streams and lakes in accordance with the DNRC Forested Lands HCP.
Unique Management Zone (UMZ)	Conservation Agreement & Easement areas, as well as Federal Wild & Scenic Corridors.
Helicopter Acres	Land parcels that can only be logged by helicopter.
Sensitive Watersheds	DNRC parcels that lie within watersheds that are designated as sensitive to increases in water yield. These watersheds have been delineated at a scale utilizing federally defined grizzly bear subunits. Harvest levels in these watersheds need to be managed within the ARMS and HCP commitments governing cumulative watershed effects.
Grizzly Bear	Areas that require special management consideration due to their status as grizzly bear habitat. Various types of grizzly bear habitat management areas exist, each with its own management considerations.
Lynx Management Areas	Areas which contribute towards existing lynx habitat, which must be managed in such a way as to maintain specific amounts of habitat.
Potential Lynx Habitat	Stands that have the potential to become lynx habitat, with management actions aimed at attaining habitat attributes.
Bald Eagle Nesting Site	Known locations of bald eagle nests, which must be managed towards maintaining the land as a nesting site.

4.2.3 Source of Stand Table Data

In its report for the 2004 calculation, MB&G recommended that DNRC acquire more plot data representative of its managed stands in order to improve on the efforts made in the 2004 and prior calculations. With that recommendation in mind, DNRC contracted with MB&G in 2013 to design a plot-based inventory effort that would support this calculation and produce an estimate of its timber inventory (expressed in board foot volume) with an allowable error of +/- 20% at the 80% confidence level.

The area of interest for the cruise included DNRC's Northwestern (NW), Southwestern (SW), and Central (CE) land offices. The cruise design used a stratified random sample to determine stands that would be cruised in each land office. Strata for each land office were defined by unique combinations of three attributes: timber type (species), size class, and stocking. The number of stands to be sampled in each land office was determined by the proportion of acres among the three land offices, and that number of stands was distributed among the strata within each land office according to their proportionate acreage within the land office. Stands from each stratum were randomly selected for sampling. This design resulted in a total of 316 sampled stands with 5,314 individual plots (Table 4).

Table 4: Number of Stands Sampled and Plots Collected by Land Office

Land Office	Stands Sampled	Plot Count
CE	37	626
NW	164	2,775
SW	115	1,913
Total	**316**	**5,314**

Each cruise plot contained a variable-radius plot for sampling trees greater than 5.0" DBH, and a 1/300-acre plot for sampling live trees less than 5.0" DBH and greater than 1 foot tall. Cruisers were required to select a basal area factor for the variable-radius plot that would yield an average of 6-8 trees sampled per plot. Required data to be collected for all trees measured on the variable-radius plot included species, group code (live, dead, broken/dead top), DBH, percent live crown ratio, and percent defect. The first and third trees on each plot also had height and 10-year radial diameter growth data collected. For the fixed-radius plot, cruisers were required to collect the following information for each tree: species, DBH, height, live crown ratio, tree count, and the average 5-year height growth.

Cruising was completed during the summer and fall of 2014 using contracted services. DNRC performed quality assurance and control on the data through check-cruising while the data were being collected and after final data files were submitted to them by the contractors. These data were submitted to MB&G for compilation for this project.

DNRC did not collect plot data for its east-side areas, which include the Eastern, Northeastern, and Southern Land Offices. For those areas, U.S. Forest Service Forest Inventory and Analysis (FIA) plot data was used to develop tree lists for DNRC's East-side timber strata. MB&G sub-contracted with BDL Forestry of Missoula, MT, to obtain FIA plot data and assign it to DNRC's East-side timber strata. BDL Forestry entered into a Memorandum of Understanding with Interior West FIA in Ogden, UT to obtain proprietary FIA plot location information. FIA provided BDL Forestry with data from FIA plot locations that were within five miles of the border of a DNRC-owned parcel. This data included individual tree-level data for each plot. BDL Forestry used photo interpretation of 2013 NAIP digital photography to assign stratum codes consistent with DNRC's SLI (and plot) data to all FIA plots that were not located within DNRC-owned parcels. For FIA plots located on DNRC-owned parcels, the SLI stratum code was assigned to the FIA plot. This process resulted in 351 FIA plots assigned to forest strata that could be used for this project. The FIA plot tree list data and linked strata codes were submitted to MB&G to compile inventory information and for use in growth and yield projections.

4.2.4 Timber Inventory Information

This section of the report describes MB&G's methodology of processing and compiling the inventory data used in the sustainable yield calculation. Three sets of inventory data were used:

- DNRC SYC cruise data for the Northwestern, Southwestern, and Central Land Offices (see 4.2.3 for description of this data).
- DNRC timber sale cruise data (this cruise data is collected before each timber sale).
- USFS FIA inventory data for the Eastern Land Office (BDL Forestry processed and assigned a DNRC stratum to each FIA plot).

Using the final version of each set of inventory data, an MBGTools[17] database was built to process the data for each Land Office. For each land office and type of data, comprehensive data quality checks were performed to assure that stands, plots, and tree lists were accurate and ready for further processing.

All the inventory data was then compiled and merchandized using MBGTools utilities. The following merchandizing specifications were specified by DNRC:

- Minimum DBH = 6 inches
- Stump Height = 1.0 foot
- Log Length = 16 feet
- Minimum Top DIB = 6 inches
- Minimum Log Length = 8 feet

[17] MBGTools is a comprehensive software system for stand-based forestry inventory data compilation and management.

- Trim Amount – 2.5 percent
- Observed tree defect from inventory data
- Scribner Decimal C Short Log Rule

MB&G then conducted an analysis to compare the SYC cruise data to the timber sale cruise data. The initial intent was to incorporate the timber sale data into the final inventory based on a derived adjustment factor. Several analyses were conducted, but ultimately, DNRC decided to use the SYC cruise data only because the correlation between the two datasets was statistically weak. With that decision, MB&G moved forward with the SYC cruise data and the FIA data in preparing the full stand level inventory.

An analysis was then conducted to determine the relative "plot strength" of each stratum in the SLI. MB&G analyzed how many strata contained cruise plots, how many did not; how many acres of each strata had plots, and how many did not. This analysis provided a foundation for developing a strategy for assigning plots to strata with no plots. Through a review process, DNRC and MB&G decided upon a final strategy that would provide reasonable stand characteristics for strata without any inventory information. See 4.2.5 for more detail.

The final step in processing the cruise data was to report the inventory for each SLI stand. In the final MBGTools database for each land office, MB&G created a stand for each of the 27,248 SLI stands. Utilizing the expansion utility in MBGTools, an average stand table was created for each of those stands based on its strata from the SLI or its assigned strata for those without plots. Each stand was then re-merchandized using the DNRC tariff equations.

A comprehensive inventory report was reviewed by DNRC and then approved before integrating the compiled inventory results into the growth and yield modeling. See Appendix K: DNRC Forest Inventory Report, for more detail on this report.

4.2.5 Stratification of Timber Types

The ultimate purpose of the inventory process was to generate a stand table (tree list) for every stand. This is however rarely possible, since cruising data is not always available for each stand. The alternative is therefore to create tree lists for the un-cruised stands from the cruised stands, but the issue becomes how to decide on which cruised stand best represents the one without cruise data (stand mapping). For the purposes of this modeling effort it was decided that this issue could be avoided by pooling the cruise plots of similar stands, creating an averaged tree list, and applying this tree list to all stands within the pool. This process is generally referred to as stratification, and in this case stands were pooled by the unique combination of their land office, species, size and stocking codes. All the plot data within a given strata was therefore averaged, and a tree list was generated that represented the average condition within the strata. This process did not deliver a tree list for every strata, because in some cases there were no plot data within certain strata. In such cases, these empty strata were assigned a tree list from a stratum with plot data that were closest in terms of vegetation. This "closeness" was determined in two ways. The first prioritized finding a match on species, followed by size, followed by stocking. The second prioritized on stocking first, followed by size, followed by species. The results from these two methods were forwarded to the DNRC, who made the final determination on this process through inspection and editing of the results.

The land office, species, size and stocking codes were generally kept the same as they appeared in the SLI. There were however two exceptions. First, stands from the Southern (SO), Northeastern (NE) and Eastern (EA) land offices were aggregated into a single land office called EA. Second, four old-growth types were identified for the NW and SW land offices, namely W1, W3, W4 and W6. Stands belonging to these types were given the old-growth code for species, size and stocking, and aggregated into old-growth strata.

Finally, for modeling purposes it was decided to grow a low, medium and high productivity variant of each stratum. To generate these variants all the strata were tripled and given one of the productivity class codes. The strata thus generated had identical tree lists for a given combination of land office, species, size and stocking, but each received a different estimate of future growth (habitat type and site index) depending on its productivity class (see 4.2.6.4).

4.2.6 Yield Table Development

This section describes the process of calibrating the growth and yield model in order to produce realistic growth estimates, as well as the application of the management pathways to the growth predictions to create the yield projections required for the LP model.

4.2.6.1 FVS Variants

For the 2015 SYC it was decided to use the Forest Vegetation Simulator (FVS) for predicting future forest conditions. FVS was developed by the United States Forest Service (USFS) and is widely used in both government agencies and private companies across the United States. About 20 variants of FVS are published by the USFS to account for variations in growth between geographic locations. To this end, the DNRC elected to use the Inland Empire (IE) variant for the NW land office, and the Eastern Montana (EM) variant for the CE and EA land offices. For the SW land office it was decided to use the IE variant for the Clearwater, Hamilton and Missoula units, and the EM variant for the Anaconda variant. Given the geographic location of these units, this approach was deemed to be aligned with the intended use of the IE and EM variants. However, upon later review of the performance of these two variants, it was determined that results obtained by using the IE variant on the Anaconda unit was better aligned with historic growth rates. It was therefore decided to use the IE variant on the whole SW land office.

4.2.6.2 Background

All yield tables were created in MBG's YTGTools. This is a custom application created by MBG, which utilizes FVS to grow tree lists forward on a period-by-period basis. After each period of growth all management treatments such as pre-commercial thinning (PCT), commercial thinning (CT) and ingrowth are implemented by adding or removing trees from the given period.

A period length of 10 years was used, implying that the period-on-period difference represented ten years of growth. The only exception to this was period one, which represented five years of growth (from period zero to period one). The rational in this was that the yield tables should show the average condition over the ten year time span, and by limiting the first growth period to five years it would initialize the yield tables at the period mid-point. Each yield table was grown for 20 periods, thereby representing 200 years of growth.

All yield tables were post-processed with a tariff equation algorithm. The purpose of this algorithm was to perform a net to gross adjustment on inventory and harvest volumes. The first step in this adjustment was to apply an age-based defect to all trees. This defect ranged from 0% at age zero to 35% at age 210+, increasing by ±1% every 5 years. The second step in this adjustment was to apply the DNRC tariff equations, which essentially applied merchandising formulas to the inventory, based on tree DBH and species. Examples of these yield tables are shown in Appendix L: Selected yield tables for NW, SW, CE, and EA.

4.2.6.3 Habitat Types

Habitat type is a vegetation classification system that is used to capture the potential forest cover that could develop on a given piece of land, as opposed to classification schemes that are limited to existing cover. Forest sites that are capable of producing similar plant communities at the culmination of plant succession, or climax, may be classified as a habitat type.[18,19] Because climax plant communities integrate the entirety of environmental factors affecting vegetative development and are the end result of plant succession, they are believed to be more stable and indicative of a site's potential future growth and development.[20] Habitat type is extensively used in both the IE and EM FVS variants. In particular it is used to parameterize site species, site index, and maximum basal area, all of which are crucial determinants of potential growth.

Early trials with both FVS variants showed that growth rates obtained by using a site specific habitat type were more realistic compared to results using default habitat types. It was

[18]Helms, JA, ed. The Dictionary of Forestry, Society of American Foresters, Bethesda, MD, 1998.
[19] Pfister *et al.*, Forest Habitat Types of Montana, USDA Forest Service General Technical Report INT-34, Intermountain Forest and Range Experiment Station, Ogden, UT, 1977.
[20] Pfister *et al*., 1977.

therefore decided to group strata by land office, species (dominant vegetation) and productivity class (site index), and that each of these groups would be assigned an appropriate habitat type for growth and yield modeling. The SLI database contains habitat types for most stands, so it was used as a starting point for the allocation process. Since multiple habitat types could exist per strata group, it was decided to allocate the habitat type based on acres (i.e. each strata group was assigned the habitat type with the most acres within the group). Where blank entries were created (i.e. no available data), habitat types were allocated from the closest productivity class within the same land office and species (no blank entries were filled across land office or species). These initial allocations were reviewed by the DNRC for accuracy, and manually adjusted where necessary. Please see Appendix O: Habitat Type Data, for the final allocation of habitat types.

4.2.6.4 Site Index

Site Index is another means to quantify site quality, and as such is an estimate of the expected potential productivity. Site index is described in terms of the expected height of dominant or co-dominant trees at a base, or index, age.[21] It is therefore used in conjunction with habitat type in the IE and EM variants to predict expected future growth.

Determining site index therefore began by assigning a productivity class (Low, Medium or High) to each stand based on its expected average productivity (ft^3/acre/year). The expected average productivity for each stand was extracted from the SLI database, while the productivity classes were provided by the DNRC. The classification scheme is shown in Table 5.

Table 5: Productivity Classes (ft^3/ac/yr.)

Land Office	Low	Medium	High
CE	20 – 49	–	50+
EA	20 +	–	–
NW	20 – 59	60 – 89	90+
SW	20 – 59	60 – 79	80+

Next, the stand level productivity estimates were aggregated up to an area weighted average productivity, for each unique combination of land office and productivity class. The resulting weighted average productivities are shown in Table 6.

[21] Helms, JA, ed., 1998.

Table 6: Average Productivity (ft³/ac/yr.)

Land Office	Low	Medium	High
CE	40	–	55
EA	30	–	–
NW	35	70	105
SW	35	70	95

Site index was derived by assigning each SLI stand a potential productivity rating (ft3/ac/yr) and then calculating the weighted average productivity estimate for each site class and land office. Potential productivity was converted to site index (DF site index base age 50) using conversion factors published in a report by Jim Brickell (Int-75)[22]. Results were reviewed for logical consistency within and between Land Offices. The resulting site index values are shown in Table 7:

Table 7: Site Index

Land Office	Low	Medium	High
CE	40	–	50
EA	30	–	–
NW	35	55	70
SW	35	55	65

4.2.6.5 Stand Age

Stand age is not a required parameter for using either variant of FVS. It is however an important parameter for allocating the silvicultural treatments that accompany some management pathways. For instance, some of the management pathways require a commercial thinning treatment at age 60. This treatment can therefore only be incorporated into the yield table if age is known. In addition, the linear programming model is age-based, and therefore needs to keep track of age throughout the planning horizon to optimize the harvest level subject to the constraints.

Assigning age to the stands managed by the DNRC is however not a simple task, since they are typically not even-aged. The SLI database does however contain an estimate of average age for most of the stands. These values were used as a starting point to determine age, resulting in an area weighted average age by land office, timber size class and productivity class. These age allocations were reviewed by the DNRC for accuracy, and manually adjusted where necessary.

[22] Brickell, James E.,Equations and Computer Subroutines for Estimating Site Quality of Eight Rocky Mountain Species", Intermoutain Forest and Range Experiment Station, USDA Forest Service Research Paper INT-75, 1970, 22 pages.

For final implementation these ages were rounded to the closest mid-decade point (15, 25, 35, etc.), which accommodated the five year growth period between periods zero and one, and allowed subsequent ages to fall on full decadal values (20, 30, 40, etc.). Please refer to Appendix P: Strata Starting Age, for more detail regarding age.

4.2.6.6 Location Code

FVS utilizes geographic location in several ways to determine localized growth rates. One of these mechanisms is the location code, which matches growth to observed growth on a USFS National Forest. Each strata were therefore assigned a location code, using the following scheme:

Table 8: Location Codes

Land Office	USFS National Forest
CE	Helena
EA	Custer
NW	Flathead
SW	Lolo

The analytical steps described in section 4.2.5 resulted in a tree list for each stratum at each productivity class level. The final step before taking these tree lists into FVS was to assign each combination of strata and productivity class with a habitat type, site index, age and location code. These parameters were the result of the analytical processes described in sections 4.2.6.3 through 4.2.6.6.

4.2.6.7 Growth Model Calibration

One of the objectives that the DNRC had for this sustainable yield calculation was to obtain better estimates of growth and yield by incorporating its own data, as well as the experience and expertise of its foresters. It was therefore decided that all growth predictions would be reviewed by a review team comprised of field staff from each land office, and that the information so gained would be utilized to verify the calibration process.

The first set of yield tables were delivered by MB&G mid-December 2014, consisting of a complete set of grow-only tables (not inclusive of any management treatments such as pre-commercial thinning, commercial thinning and selection harvest). The purpose of these yield tables was to establish a reference point for future calibration. Also, by limiting the tables to the grow-only management pathways, review could be focused on growth without the influence of active management. The only parameters fully specified was site index, age and location (the default habitat type was used). General consensus was that the predicted growth rates were unrealistically high, and that the calibration effort should focus on lowering these to observed levels.

What followed was a series of trials aimed at identifying the parameters that were resulting in the unrealistic growth, and the calibrations required to align these parameters with observed growth. Early trials showed that the results were highly sensitive to habitat type, so each stratum was supplied with the appropriate habitat type. This improved the results, but growth was considered still too high. This raised a question about what is the expected growth rates. This was answered through two separate analyses. The first compared FVS growth rates with data from the 2004 SYC, and benchmarked the FVS growth rates against the 2004 SYC. The second compared the growth of younger strata with the measurements from older strata, with the objective to determine if the FVS growth results passed through the cruised data points. The conclusion reached from both these analyses was that FVS tended to grow basal area (BA) at higher than expected rates. It was therefore decided to control BA growth by specifying a maximum stand density index (Max SDI) for each strata. These Max SDI values were obtained by referencing the maximum SDI values observed in the 2004 yield predictions. The results from this calibration was judged to be favorable for the EM variant, but not so for the IE variant. The Max SDI calibration was therefore only adopted for strata using the EM variant. It was also noted that diameter at breast height (DBH) growth was faster than expected, since the quadratic mean diameter (QMD) values returned by FVS trended higher than the measured values. It was therefore decided to slow down DBH growth for both FVS variants by a constant factor for each stratum. The value of these factors were calculated as the average ratio between the SYC 2004 QMD and the QMD returned by FVS without DBH calibration.

Following the recalibration of FVS (site specific habitat type, capped Max SDI and reduced diameter growth), MBG delivered a second set of grow-only yield tables towards the end of January 2015. These yield tables were once again reviewed by land office staff. Reviewers generally agreed that growth rates appeared much more realistic. At this point FVS was considered fully calibrated, and focus shifted towards generating yield tables inclusive of active management.

4.2.6.8 Management Regimes

The next step in the yield table development was to model the effect of active management through the inclusion of stand treatments such as pre-commercial thinning (PCT), commercial thinning (CT) and selection harvest. Two main types of management pathways were formulated, namely even-aged prescriptions (EARX) and uneven-aged prescriptions (UERX). The distinction between these two types is that EARX incorporates a regeneration harvest (majority of stems removed), while the UERX incorporates selection harvest (partial harvest only). A third management pathway was also developed for the old-growth strata (OGRX), which also incorporated selection harvest, but with residual tree targets aimed at maintaining old growth status. For those pathways with a PCT treatment the stem reduction was modeled as a thin-from-below (remove smallest trees until target is reached), while the CT stem reductions were modeled as a weighted thin (remove equal proportions from all DBH classes until target is reached). A minimum harvest threshold of 1,000 BF (before tariff equations are applied) was established, so all thinning treatments falling short of the threshold were skipped.

Three different types of EARX pathways were developed, namely clear-cut prescriptions (CCRX), seed-tree prescriptions (STRX) and shelter-wood prescriptions (SWRX). These three types were distinguished by the amount of over-story that was retained after regeneration harvest, with CCRX retaining 4 trees per acre (TPA), STRX 8 TPA and SWRX 30 TPA. These types were further subdivided by the type of management treatments applied, which varied the inclusion and timing of PCT and CT. The availability of these pathways to individual strata was defined by land office, forest type (species) and productivity class. A detailed summary of all the EARX pathways can be found in Appendix D: Management Pathways. Pathways with a CT received five timing options, creating the option to optimize the timing of a CT over a 50 year period. EARX options were also created for each old-growth strata, but these were limited to options without PCT and CT since all the old-growth strata were beyond the age of these treatments. The same was true for saw-log size class strata that would be beyond the age of all PCT or CT treatments, and therefore would not receive a pathway that would include those options.

Three different types of UERX pathways were developed to accommodate Dry, Moist and Wet sites. Eligibility for these types was determined by land office and forest type. These types were further subdivided by whether a PCT was included or not. All of these types simulated selection harvest by periodically removing trees according to a target DBH distribution. Periodic entries ranged from 30 to 40 years, depending on prescription type. The target distributions were generated by defining the total BA, the Q-factor for the distribution, the DBH range and the DBH class size. Appendix E: Selection Harvest Reversed J-Curves, contains a detailed description of these curves. A number of trial runs were required to fully specify these distributions, since early efforts tended to remove too much BA. This was primarily due to the fact that a large difference in BA existed between the starting and ending conditions. In the end a tiered approach was adopted, which incrementally reduced BA until the target level was reached. A detailed summary of all the UERX pathways can be found in Appendix D: Management Pathways.

The UERX also included the ingrowth of young trees following a selection harvest, simulating the development of regeneration and understory development following a disturbance event. The tree lists used for ingrowth were based on the SYC 2004 data (with some modifications and additions), while tree list and strata matching was performed by the DNRC. These tree lists generally represented ten year old trees, so they were inserted into the yield table ten years after the selection harvest. For pathways with PCT, a stem reduction (thin-from-below) was inserted 20 years after the selection harvest.

The OGRX were formulated in a similar manner to the UERX. That is they consisted of periodic selection harvests that reduced the trees to a certain target. In this case the target was a minimum BA threshold. In addition, the residual trees had to contain a certain number of large trees, with large trees being defined by a minimum DBH threshold. Periodic entries ranged from 30 to 50 years, depending on old growth type. No PCT treatments were included, since all of these strata were beyond PCT age. A detailed summary of all the OGRX pathways can be found in Appendix D: Management Pathways.

A full set of yield tables inclusive of management prescriptions were sent for review to DNRC's field review team mid-February 2015. General consensus was that the management treatments were adequately implemented, and that the volume removals were consistent with reality.

4.2.6.9 Regeneration Yields

Regeneration yield tables are required to fully model the application of even-aged regimes (EARX). The basic principle is that these types of regimes result in a complete stand replacement after final harvest, with age resetting to zero. Stands receiving this type of harvest will therefore have to transition to a new yield table, which represents the growth associated with the regenerated stand. Uneven-aged (UERX) and old-growth regimes (OGRX) do not require regeneration yield tables, because harvesting does not result in stand replacement. New growth in these stands is modeled through ingrowth tree lists inserted into the yield tables a specific number of years after harvest.

The implementation of regeneration yield tables is complicated by the fact that EARX can take on three different forms, namely clear-cut (CCRX), seed-tree (STRX) or shelter-wood (SWRX). Each one of these types of management pathways will receive different intensities of regeneration harvest, resulting in different stand structures being passed on to the regenerated stand. CCRX will pass on 4 TPA of the largest trees, STRX 8 TPA, and SWRX 30 TPA. This implies that the regeneration yield tables will have a different over-story component (at age zero) for each of these types. In addition, each of these types will have a different approach to over-story removal (second harvest to remove a portion of the leave trees). CCRX will have no over-story removal, while STRX will be reduced from 8 TPA to 4 TPA at age 10, and SWRX will be reduced from 30 TPA to 4 TPA at age 20.

Incorporating all of these components into the regeneration yield tables therefore took careful consideration. The composition of the over-story tree lists were determined by applying the appropriate final harvest at the earliest possible age to each combination of existing strata and EARX. This provided a tree list of residual trees that could be expected after final harvest, which was then summarized by land office, timber type and Rx. These tree lists were then inserted into the corresponding regeneration yield table at age zero.

The second component to incorporate was the partial over-story removal (second harvest). This was implemented as a thinning treatment that left a predetermined number of trees in the appropriate DBH range. This step was only implemented for STRX and SWRX, since CCRX had no over-story removal. For STRX the thinning treatment therefore reduced the 10+" DBH class to 4 TPA at age 10, and the same thing for SWRX at age 20.

The third component in these yield tables was the regeneration trees that would grow in underneath the over-story trees. It was determined that these tree lists would be best approximated by using the tree lists from the Seeds & Saps timber size class (Size Class 7). A DBH threshold of 3” was used for these tree lists, which resulted in only the small trees making it into the regeneration yield tables. In some cases such a tree list did not exist for the regenerated strata, in which case the closest match in terms of species, size and stocking was used. In generating the rules for transitioning from existing to regenerated strata, the assumption was made that poorly stocked strata would regenerate as moderately stocked strata, while existing moderately and well stocked strata would remain the same. In certain cases a species change was also implemented to better represent expected natural processes and DNRC’s management toward desired future cover types. These species[23] changes are summarized in Table 9.

Table 9: Regeneration Species Changes

Existing Species	CE	EA	NW	SW
GF			DL	DL
MC	D	D	DL	DL
NS	D	P	DL	D
S	AF			
WH			C	

The regeneration yield tables also received all of the treatments that were applied to the EARX for the existing strata. I.e., all of the PCT and CT options were made available in addition to the over-story components described above. This implies that some pathways received both an over-story removal and PCT harvest in the same period. For such cases, a 10” DBH threshold was used, resulting in trees less than 10” DBH participating in the PCT treatment (thin across DBH classes), and trees greater than 10” DBH participating in the over-story removal (thin across DBH classes).

4.3 Formulation of the Montana Forest Management Model

The following sections will describe the general structure of the optimization model, followed by a detailed discussion of the various components.

[23] AF – Subalpine Fir, C – Western Redcedar, D – Douglas-fir, DL – Douglas-fir/Western Larch Mix, GF – Grand Fir, MC – Mixed Conifer, NS – Non-Stocked, S – Spruce, WH – Western Hemlock

4.3.1 Structure of Forest Management Optimization Model

The optimization model used for this SYC took the form of a linear programming (LP) formulation. This type of formulation is well suited to strategic/tactical level harvest optimizations, since these problems can typically be formulated through a system of linear equations. In addition, given a feasible problem, the LP will always solve to the absolute optimum, which ensures that the best possible solution is always found. The LP model used for this SYC was built in Remsoft's Spatial Planning System. This application provides an environment for rapid development of LP models, coupled with the ability to incorporate data from various sources, manage and run various scenarios, and report results in an easily retrievable manner.

The main structure of the model consists of analysis areas, actions plus transitions, yield projections, and objectives plus constraints. The analysis areas describe the existing condition of the land, as well as alternatives that could be realized in the future. Actions and transitions are responsible for placing land onto various management pathways, converting existing condition into future condition. The yield projections quantify the contribution that one acre of land in a given condition would make to various parameters being tracked. These parameters take on several forms, ranging from timber volume to wildlife habitat, and are used to calculate various outputs used in the objective, constraints and reports sections. Objectives and constraints are the model elements respectively used for optimizing the model and constraining the solution to be within certain parameters. For this SYC the objective was to maximize the total harvest volume across the planning horizon, while the constraints limited the management activities and required various habitat thresholds to be maintained.

Model results were reported by planning period, with one period representing 10 years. The planning horizon was 20 periods, resulting in the model scheduling activities for the next 200 years.

4.3.2 Analysis Areas

The analysis area used for this study is defined as all commercial forest land on State Trust Lands throughout Montana, partitioned into administrative units and areas of special consideration. These areas describe both the existing condition of the land, as well as the future options. As such this section of the model is initialized through an imported geographic information system (GIS) layer, while the future options are created through a series of actions and transitions. The GIS layer used in this SYC was based on one provided by the DNRC. This layer essentially contained all of the stand boundaries (coded for land office, unit, species, size, stocking and productivity class), intersected with the boundaries of various operational and wildlife features (deferred acres, grizzly bear, lynx management areas, etc.). MBG passed this GIS layer through a number of processes which essentially converted it into a format that was compatible with the LP model. These processes revolved around adding thematic layers to the data, with each theme describing a unique feature. A total of 25 themes were created in this way. Table 10 provides a description of each of these layers, as well as whether it was ultimately used in the model or not. Appendix C: Acres in the Forest Management Model, contains a summary of the acres in various themes subdivided by thematic codes.

Table 10: LP Model Thematic Layers (Themes)

Theme	Name	Description	Used
1	Strata ID	A four part code, denoting the land office, species, size and stocking of the stratum that the stand belongs to.	No
2	Land Office	The land office that the stand belongs to.	Yes
3	Unit	The administrative unit that the stand belongs to.	Yes
4	Species	The species code used by the stratum to find the appropriate yield table. Not necessarily the same as the one in Strata ID.	Yes
5	Size	The size code used by the stratum to find the appropriate yield table. Not necessarily the same as one in Strata ID.	Yes
6	Stocking	The stocking code used by the stratum to find the appropriate yield table. Not necessarily the same as one in Strata ID.	Yes
7	Productivity Class	The stratum productivity class.	Yes
8	Start Age	The age of the stratum in period zero.	No
9	Deferred	Designates the land parcel as deferred or not.	Yes
10	Rx	The management pathway allocated to the land parcel. All start off on grow-only (E++++GO).	Yes
11	Timing	The timing option associated with the given Rx that was selected. Created the option to delay the start of the treatments associated with a management pathway.	Yes
12	Rotation	Denotes whether the land parcel has existing or regenerated tree cover.	Yes
13	Sensitive Watershed	Denotes whether a land parcel is in a sensitive watershed or not, as well as the name of the watershed.	Yes
14	UMZ	Designates whether the land parcel is within a unique management zone or not.	Yes
15	Helicopter	Designates whether the land parcel is within an area requiring helicopter logging or not.	Yes
16	RMZ	Designates whether the land parcel is within a riparian management zone or not.	Yes
17	GZB Visual	Designates whether the land parcel is within a grizzly bear visual buffer or not.	Yes
18	GZB Class A	Designates whether the land parcel is within a grizzly bear Class A area or not, as well as the name of the Class A area.	No

Theme	Name	Description	Used
19	GZB Core/ Security Zones	Designates whether the land parcel is part of the Grizzly Bear Core or Grizzly Bear Security Zones located on Stillwater Unit or not.	Yes
20	GZB Subzone	Designates whether the land parcel is within an HCP grizzly bear Class A Subzone or not, as well as the identifying number of the subzone.	No
21	LMA	Designates whether the land parcel is within a Canada lynx management area (LMA) or not, as well as the name of the LMA.	Yes
22	Potential Lynx	Designates whether the land parcel is flagged as potential Canada lynx habitat or not.	Yes
23	Eagle	Designates whether the land parcel is part of a known bald eagle nesting area or not.	Yes
24	OG Recruit	Designates whether the land parcel could be recruited into OG or not.	No
25	OG Current	Designates whether the land parcel is currently OG or not.	Yes

In addition to the thematic layers described above, the model also required the surface area (acres) of each land parcel and the age at period zero. Age was obtained from the strata data, while the area was already calculated in the GIS layer. Once all of this data was complete, the LP model imported the data and created existing development types. Development types are a way for the model to aggregate data and reduce the computational overhead. This aggregation is done on unique combinations of thematic codes and age (i.e.—all land parcels with the same combination of thematic codes and age would have been grouped into the same development type). Acres are summed during aggregation. In total, the model imported 729,379 acres from 51,963 polygons. From this the model created 10,086 development types representing the existing land. 14,527 (28%) of these development types were less than one acre in size, representing 4,196 acres (0.6%).

4.3.3 Actions & Transitions

A series of actions and transitions were incorporated into the model to generate the various management pathway options that the model could utilize. These actions and transitions therefore generated additional development types, collectively called the future development types. In total, 177,947 development types were generated, of which 167,861 (94%) were future development types.

Two main forms of actions and transitions were used. The first occurred only in period one, and determined the management pathway used by each development type. All acres were initialized at the beginning of the planning horizon (period zero) on the grow-only (no management) pathway, so the main function of these actions and transitions was to take acres out of the grow-only pathway, and place them onto a managed pathway. An action and transition was created for every unique combination of management prescription and timing option. The actions were used to filter out those acres that possessed thematic codes appropriate for the action being considered, while the transitions placed the acres onto the new prescription and timing option.

The second set of actions and transitions determined when a regeneration harvest would occur for the even-aged regimes. These could occur anywhere along the planning horizon, given that sufficient harvest volume was available and the minimum harvest age of 80 years had been reached. In addition, the actions also filtered the acres to apply the regeneration harvest only to those acres which had the appropriate thematic codes. The transitions were responsible for taking acres from their existing yield table and placing them onto the regenerated yield table, by changing the appropriate thematic codes. In some cases this meant a change in species and stocking codes. In all cases this meant resetting age to zero and changing size class to Seeds and Saps (size class 7).

It was noted that the approach described thus far placed a severe limit on the management options available to older strata, such as the saw timber and poles size classes. The reason for this is that none of these strata would have received an even-aged option which included a PCT or CT treatment, since all of them were beyond the age of these treatments. When these strata got regenerated, they were forced to go back to the even-aged pathway with no treatments, because the model did not allow for them to change pathways after period one. This was despite the fact that most regeneration yield tables could deliver better yields if these treatments were performed. It was therefore decided to relax this limitation on selecting pathways, by allowing the older strata to reselect a pathway at the time of regeneration harvest, as long as it stays within the same type of even-aged pathway (for example, if it was already on a seed-tree pathway, it can only select from the pool of seed-tree pathways).

As mentioned above, actions filtered out those acres with thematic codes appropriate to the action being considered. The rationale behind this was to minimize the model size, by only creating those development types that were feasible options. This resulted in acres being both allocated and constrained through the actions. Allocation is when a strata is limited to the pathways it can take based on its land office, species and productivity class (only AF and LP species, on medium productivity, on NW and SW land office can receive a CC pathway with CT), while constraining is when acres are excluded from certain management pathways due to a limitation on the amount of management that could done (no even-aged management on grizzly bear visual buffers). These limitations however, placed a severe restriction on the calculation of biological potential (the potential harvest level without considering allocation and constraints). It was therefore decided to relax the allocations and constraints in the actions, and rather control them through the constraints in the optimize section. This allowed the model the ability to take these pathways when they were allowed, and restrict them when they were not.

4.3.4 Yield Projections

Yield projections are introduced into the model to calculate the contribution that one acre of land is making in a given planning period to various parameters. These parameters are generally called outputs, and can take on numerous forms, ranging from harvest volumes, to wildlife habitat, to revenues. In terms of LP modeling, yield projections can be described as the coefficients that are associated with variables tracking the amount of acres allocated to a given development type in a given period. Yield projections are therefore specified for a specific development type (or group of development types) in a specific period. The majority of these yield projections were developed through the growth and yield work described earlier (see section 4.2.6). A total of 7,080 yield tables were developed through this process, each with 19 yield projections. Additional information about the number and distribution of yield tables can be found in Table 11.

Table 11: Yield Table Count

Existing/Future Development Type	Rx Type	Count
Exist	Grow Only	636
Exist	Even-Aged Clear-Cut	224
Exist	Even-Aged Seed-Tree	1,006
Exist	Even-Aged Shelter-Wood	1,188
Exist	Uneven-Aged Dry Site	1,016
Exist	Uneven-Aged Moist Site	1,044
Exist	Uneven-Aged Wet Site	720
Exist	Old-Growth W1	18
Exist	Old-Growth W3	18
Exist	Old-Growth W4	30
Exist	Old-Growth W6	30
Future	Even-Aged Clear-Cut	101
Future	Even-Aged Seed-Tree	481
Future	Even-Aged Shelter-Wood	568
Total		**7,080**

The following yield projections were associated with these yield tables:

- Age in years
- Standing inventory in MBF/Acre before harvest, after defect and tariff equations

- Timber volume removed in MBF/Acre through commercial thinning and selection harvest, after defect and tariff equations
- Standing inventory of Douglas-fir and Western Larch in MBF/Acre before harvest, after defect and tariff equations
- Standing inventory of Grand Fir and Western Hemlock in MBF/Acre before harvest, after defect and tariff equations
- Standing inventory of Ponderosa Pine in MBF/Acre before harvest, after defect and tariff equations
- Standing inventory of Western redcedar in MBF/Acre before harvest, after defect and tariff equations
- Standing inventory of Engelmann Spruce and Lodgepole Pine in MBF/Acre before harvest, after defect and tariff equations
- Standing inventory of Western White Pine in MBF/Acre before harvest, after defect and tariff equations
- Standing inventory of Subalpine Fire, Mountain Hemlock and Whitebark Pine in MBF/Acre before harvest, after defect and tariff equations
- Basal area in ft^2/Acre after harvest
- Total stems per acre after harvest
- Stems per acre larger than or equal to 13" DBH after harvest
- Stems per acre larger than or equal to 17" DBH after harvest
- Stems per acre larger than or equal to 21" DBH after harvest
- A PCT flag, used in certain outputs to determine if a PCT harvest occurred or not
- Valid yield table flag, used to prevent the model from assigning acres to development types that do not have a valid yield table

In addition to the yield projections described above, projections were included for implementing the residual tree volumes associated with the even-aged pathways. As described earlier, the even-aged pathways were sub-divided into three types, namely clear-cut (CCRX), seed-tree (STRX) and shelter-wood (SWRX). These three types were distinguished from each other based on the number of over-story trees remaining after even-aged harvest, as well as the intensity and timing of subsequent over-story removal. In short, CCRX kept 4 TPA as over-story with no second entry, STRX kept 8 TPA as over-story which was reduced to 4 TPA at age 10 years, and SWRX kept 30 TPA as over-story which was reduced to 4 TPA at age 20. In terms of yield projections, the net volume of the regeneration harvest was determined by subtracting the volume of the leave trees from the standing inventory. The volume of the leave trees were determined by simulating each type of harvest on the appropriate strata, and analyzing and summarizing the residual volume by land office, species and harvest type. This however, created the possibility that the residual volume could be greater than the standing volume. To avoid this, a special yield projection was created that tracked the volume available for regeneration harvest. This projection was equal to zero, unless the management pathway was even-aged, age was greater than 80 years, and the difference in standing inventory and residual trees was greater than or equal to 1 MBF (minimum harvest volume of 1,000 Bf). This yield projection was used to calculate the harvest volume from regeneration (first) harvest. To accommodate the over-story removal, a second set of yield projections was entered to represent the potential harvest volumes. These volumes were determined by simulating each type of harvest on the appropriate strata, followed by an analysis and summary of the tree volumes that could be harvested during over-story removal. These values were aggregated by land office and species. This yield projection was used to calculate the harvest volume from over-story (second) harvest. The sum of the first and second harvest therefore formed the total harvest volume from even-aged pathways.

Yield projections were also created to distribute management acres proportionally to the various management pathways. The rationale behind this was that the attainment of a desired future condition is reliant on the management pathways that are allocated, and that this condition can only be reached if pathways are allocated in the correct proportions. For instance, timber harvest would theoretically be maximized through even-aged harvest, but the resulting landscape would not approach the desired future condition. A series of thresholds are therefore required, that limit the allocation of acres to management pathways. These thresholds were established through a number of yield projections, which proportionally assigned acres to thresholds for CCRX, STRX, SWRX and UERX. These yield projections were defined by unit and species, and were compiled by the DNRC in accordance with published norms. Using historic forest inventory data for climatic sections in Montana[24], DNRC estimated the proportions of possible stand replacing and non-lethal disturbances that occurred for each species group in each climatic section. From those estimates, DNRC then prescribed allocation of even-aged pathways in accordance with the stand-replacing proportion for each species and administrative unit, and uneven aged pathways in accordance with the non-lethal proportion.

Economic data was also incorporated into the LP model through a series of yield projections. For the purposes of SYC 2015, it was decided to limit the application of economic data to the stumpage revenues realized through timber sales. Average bid price ($/Ton) on sales and permits, weighted by volume, were provided by the DNRC on a land office basis for 1999 to 2014. These values were in nominal terms, and were adjusted to 2014 dollars through an annual Gross Domestic Product (GDP) deflator. The resulting values were converted to $/MBF using a 6.5 Tons/MBF conversion ratio. The resultant values were incorporated into a stumpage revenue for each land office.

[24] Losensky, BJ, Historical Vegetation of Montana, Report for MT DNRC Contract #970900, 1997.

4.3.5 Objectives and Constraints

Within the LP modeling framework, objectives are the mechanism whereby results are optimized, while constraints limit the solutions to pre-defined thresholds. An LP solution will therefore always contain an objective function that has been optimized, subject to meeting the constraints that were established.

In terms of the SYC 2015 model, the objective was to maximize total harvest volume, where total harvest volume was defined as the sum of the harvest volume in each period across the planning horizon (20 periods). Periodic harvest volume was calculated as the sum of the periodic harvest volumes from even-aged pathways and uneven-aged pathways. The sum of the periodic harvest volumes from even-aged pathways was inclusive of volumes from commercial thinning, regeneration harvest (net volume from first harvest) and over-story removal volume (second harvest volume). All of these volumes were inclusive of the volume from helicopter acres, which implies that the helicopter acres participated in the objective function.

To ensure equity between current and future beneficiaries of the State forest trust lands, it is important to maximize the short term harvest that can be sustained over the 200 year planning horizon. However, it is also important to know whether future harvests could be sustained at a higher level, perhaps as a result of investments in stand improvement, forest regulation, etc. The LP objective function, therefore, must emphasize the short term harvests, while also recognizing benefits from long term improvements. This dual objective is achieved by discounting the harvest of each period. We used a discount rate of 30% – a figure high enough to ensure that the model will harvest stands when they become available for harvest, but low enough to give the model an incentive to increase future sustainable harvests, if possible.

A number of constraints were established to limit the optimal solution to pre-determined limits. All constraints were applied on a per period basis. The purpose of these constraints can be classified as either non-declining yield (NDY), protection of wildlife habitat, water resources, application of silvicultural regimes, operational limits, or LP error control.

A single NDY constraint was established to ensure that the optimum harvest levels can be maintained over the length of the planning horizon. In this case a non-declining flow constraint (period-on-period increase, but no decrease) was used, as opposed to an even-flow constraint (equal period-on-period volumes). The rationale behind this was that it could be theoretically possible for the model to harvest more volume in the future as new and improved development types became available. Using the NDY constraint would make this extra volume accessible, since the SYC level can increase (not decrease); while the even-flow constraint would make it inaccessible due to the fact that no increase (or decrease) is allowed. The NDY constraint also excluded the volume from helicopter logging acres. The fact that these acres were included in the objective function resulted in them being scheduled for harvest, but not contributing to the sustainable yield level. Their contribution is therefore purely opportunistic, which is more in line with current management approaches.

Table 12: Non-Declining Yield Constraint

Constraint	Group	Description
Non-Declining Yield	NDY	Total harvest volume exclusive of volume from helicopter acres can increase period-on-period, but cannot decrease.

The wildlife habitat, water resource, and management constraints were directed towards protecting water resources by maintaining water quality, maintaining the levels of existing wildlife habitat, or limiting the intensity of management on existing habitat, or requiring certain levels of habitat development. The wildlife habitat, water resource, and management constraints are summarized in Table 13. Please refer to section 4.2.2 for more detail on each constraint theme. Appendix B: Compatibility Matrix, contains additional information pertaining to the constraints. All listed endangered, threatened, sensitive, and big game species for which DNRC has management obligations under administrative rules were considered during the development of constraints for the calculation. Appendix Q: Wildlife Habitat , contains information and notes regarding constraint development, and inclusion/exclusion rationale for all species considered in this study.

Table 13: Wildlife Habitat, Water Resource and Management Constraints

Constraint	Group	Description
Snags	BIO NET	Requirements for the retention of snags and snag recruits were addressed in the design of the management regimes for this calculation. Volume necessary for snag maintenance was constrained as a part of the residual volumes and trees per acre retained in each allowable prescription. See Appendix D: Management Pathways.
Deferred	DEF	No treatment was assigned to deferred acres. All deferred acres (Theme 9 = Y) must be assigned to grow-only management pathways.
RMZ	RUMZ	All riparian management zone (RMZ) acres (Theme 16 = Y) must be assigned to grow-only management pathways.
UMZ	RUMZ	No unique management zone (UMZ) acres (Theme 14 = Y) can be assigned to even-aged management pathways.
Old Growth	OG	At least 8% of acres must meet the old-growth criteria for the NW and SW land offices on a unit basis, and 4% of acres must meet the old-growth criteria for the CE land office on a unit basis. Old-growth acres were contributed from two sources, namely existing old-growth and recruitment. Existing old-growth acres are existing acres

<table>
<tr><th>Constraint</th><th>Group</th><th>Description</th></tr>
<tr><td></td><td></td><td>classified as either W1, W3, W4 or W6, prior to receiving an even-aged harvest. Recruitment acres are those acres not currently classified as existing old-growth but that met the old-growth criteria at a future point in the planning horizon. For the NW and SW land offices these acres could be recruited into either W1, W3, W4 or W6, with the following criteria:
<table>
<tr><td>Group</td><td>Species</td><td>Age</td><td>BA</td><td>TPA</td></tr>
<tr><td>W1</td><td>D, P</td><td>160</td><td>60</td><td>8 @ 21”</td></tr>
<tr><td>W3</td><td>LP</td><td>130</td><td>80</td><td>10 @ 13”</td></tr>
<tr><td>W4</td><td>C, DL, GF, L, MC, WP, WH</td><td>170</td><td>80</td><td>10 @ 21”</td></tr>
<tr><td>W6</td><td>AF, S</td><td>170</td><td>60</td><td>10 @13”</td></tr>
</table>
For the CE land office recruitment acres had to meet the following criteria:
<table>
<tr><td>Species</td><td>Age</td><td>BA</td><td>TPA</td></tr>
<tr><td>D, P</td><td>180</td><td>50</td><td>5 @ 17”</td></tr>
</table>
The age used in these classifications were average stand age, as opposed to the age of the oldest trees used in Green et al.[25], and will therefore be lower than the published criteria.</td></tr>
<tr><td>Sensitive Watersheds</td><td>SEN</td><td>No more than 36% of acres in each sensitive watershed can be younger than age 40 years.</td></tr>
<tr><td>GZB Visual Buffers</td><td>GZB</td><td>Only uneven-aged management pathways are available. No even-aged management pathways in grizzly bear visual buffers (Theme 17 = Y)</td></tr>
<tr><td>GZB Core/ Security Zones</td><td>GZB</td><td>All Grizzly Bear Core and Security Zone acres in Stillwater Unit (Theme 19 = Y) must be assigned to grow-only management pathways.</td></tr>
<tr><td>Lynx Management Area LM1</td><td>LMA</td><td>At least 65% of acres in each LMA must meet canopy cover criteria, which is defined as 180 TPA when age < 40 years, or BA 50 when age >= 40 years.</td></tr>
<tr><td>Lynx Management Area LM2</td><td>LMA</td><td>No more than 15% of acres (per period) in each LMA can receive a regeneration harvest from an even-age pathway.</td></tr>
<tr><td>Lynx Management Area LM31</td><td>LMA</td><td>At least 20% of acres in each LMA must be in the saw-log size class, with BA at least 60, and must possess inventory in either Subalpine Fir, Spruce or Grand Fir.</td></tr>
<tr><td>Lynx Management Area ITP</td><td>LMA</td><td>Limit PCT to 12,000 acres per period across all LMA’s, allocated proportional to each LMA based on LMA acres.</td></tr>
</table>

[25] Green, P, J. Joy, D. Sirucek, W. Hann, A. Zack, and B. Naumann. Old-Growth Forest Types of the Northern Region. USDA Forest Service, Northern Region, Missoula, MT, 1992.

Constraint	Group	Description
Potential Lynx Habitat	POT	On non-LMA lands, at least 65% of acres flagged as potential lynx habitat (Theme 22 = Y), must meet canopy cover criteria, which is defined as >=180 TPA when age < 40 years, or BA 50 when age >= 40 years.
Bald Eagle	EAG	All bald eagle nesting site acres (Theme 23 = Y) must be assigned to either uneven-aged moist-site or wet-site management pathways, as well as maintain 60 BA.

The purpose of the silvicultural regime constraints was to steer the land base towards the desired condition by limiting the acres that can be allocated respectively to even- and uneven-aged management. These limits tie-in with the management allocations defined in the yield projections.

Table 14: Silvicultural Regime Constraint

Constraint	Group	Description
Even-Age Rx	EAR	Acres allocated to CCRX, STRX, SWRX and UERX cannot exceed the allowable thresholds established for each species and pathway group by DNRC administrative Unit (see Appendix N: Silvicultural Regime Acre Constraints).

The operational limits constraint limited the volume from helicopter acres to a level that was feasible considering market limitations assessed over the last 20 years.

Constraint	Group	Description
Helicopter	HEL	Total harvest volume from helicopter acres (Theme 15 = Y) cannot exceed more than 2% of the periodic harvest volume for each period exclusive of volume from helicopter acres (NDY volume).

The LP error control constraint prevented the model from allocating acres to development types that were ineligible, with ineligibility defined as development types without a yield projection for growth.

Constraint	Group	Description
Valid Yield	VAL	All acres must be assigned to a yield table with a valid flag value (1).

5 Results

5.1 Qualifications

The LP model used in this sustainable yield calculation is capable of producing detailed stand-level results. The temptation therefore exists to interpret these results as indicators of how each stand should be managed, and what could be expected from each stand along its management pathway. This would however be an incorrect interpretation, since the data used to run these models were highly aggregated. That is, the inventory data used in this analysis were collected from plots distributed over a range of stands, which were aggregated and mapped into strata, resulting in an average condition for each strata. So although detailed, the results represent the average condition across a range of stands within a given strata, as opposed to the condition within a given stand. Furthermore, the objective of this study was to determine a strategic direction for the DNRC in terms of sustainable annual harvest. The results of this study are therefore only interpretable at the strategic planning level, since the constraints associated with site-specific operational planning were not considered in this analysis.

The interpretation of the model results should however, not be limited only to the annual harvest level, since it is also important to examine the factors that contribute towards a given sustainable harvest level. In this regard it is essential to take note of the management pathways that were selected by the model, and the importance of these pathways in achieving the calculated harvest level. It would be inappropriate to conclude that all acres should be managed exactly like the modeled acres. However, if a general shift towards managing along a given group of pathways is observed in the model results, then it should be considered for incorporation into the DNRC's tactical and operational selection of harvest treatments that are applied on the ground.

5.2 Discussion of Model Results

The final runs of the LP model were conducted at a state-level with all acres optimized in a single model, as opposed to a land office by land office approach where the model is solved in four separate parts (one for each land office or land office aggregate). The land office by land office approach restricts the number of options that the model can select, which results in lower yield outputs for the given land-base. DNRC managers chose to select the outputs from the state-level, which was deemed reasonable because flexibility in harvest level among units and land offices is allowable and expected within the current operating environment.

At the time of publishing the Draft 2015 SYC Report, DNRC was enjoined from activities in the Stillwater Unit Grizzly Bear Core per a U.S. District Court Order. Therefore, MB&G modeled two possible scenarios – one, if the injunction was lifted, and two, if the injunction stayed in place. The two scenarios of the state-wide model were called Unconstrained Grizzly Bear Core and

Constrained Grizzly Bear Core. The Unconstrained Grizzly Bear Core scenario allowed for management within 38,470 total acres of Grizzly Bear Core, while the Constrained Grizzly Bear Core scenario excluded all management from the Core.

Since publication of the Draft 2015 SYC Report, DNRC has reached a settlement agreement with the plaintiffs in the U.S. District Court case. Therefore, a third model scenario was developed to reflect the terms of the settlement, which designated 22,007 total acres in the Stillwater Unit as Grizzly Bear Security Zones, where active management would generally be excluded.

A fourth model scenario was developed to determine the impact of the recent land acquisitions on the annual sustainable yield.

5.2.1 Scenario 1 – Constrained Grizzly Bear Core

This scenario constrained management within the Grizzly Bear Core, which encompasses a total area of 38,470 acres of the Stillwater Unit (of which 34,364 acres are commercial forest). Under this model scenario, the Core is not available for harvest. However, the net reduction in manageable commercial acres is only 18,043 acres, since 8,595 acres within the Core are already deferred for other reasons, while 6,886 acres of helicopter and 839 acres of RMZ are not available for management.

The model was run at the statewide level and in a step-wise manner, incrementally adding constraints to the model to assess their impact. These incremental steps are discussed and illustrated in the following sections and Figure 2. With all constraints applied (EAG model), a total of 561,610 acres were allocated to management regimes (included in solution), and 167,768 acres were excluded from management. Under this scenario a harvest level of 55.5 MMBF/Year can be maintained.

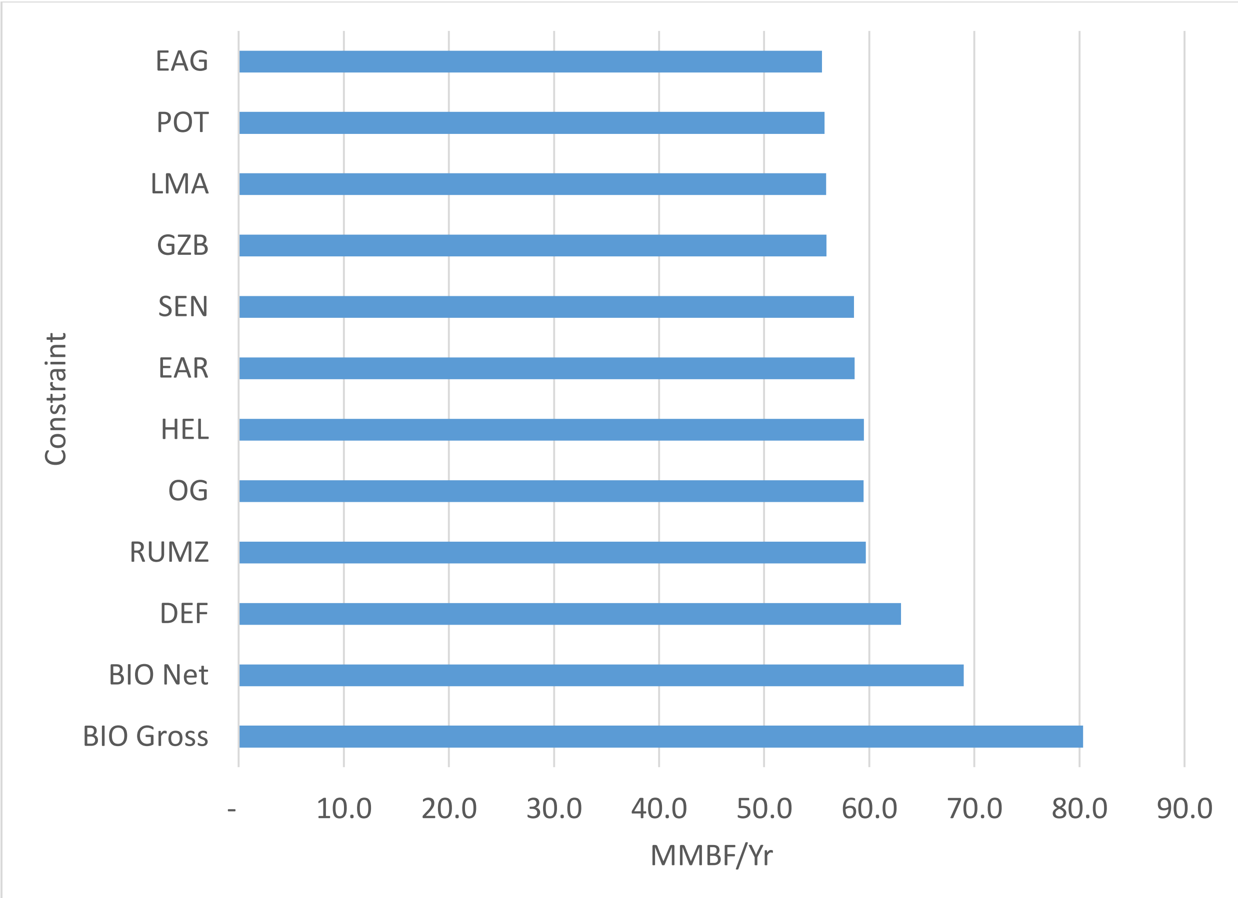


Figure 2: State – Wide Sequential Results with Grizzly Bear Core Constrained

5.2.1.1 GO – Grow Only

During the grow-only run all constraints were switched off, and the model was forced to send all acres to no-management pathways by maximizing the acres in no-management. The results were used to assess growth, inventory and the ability of the model to meet constraints. With regards to growth it was observed that the average growth across the state was 111 Bf/Acre/Year. Growth rates observed at the land office level were 159 Bf/Acre/Year for the NW, 112 Bf/Acre/Year for SW, 54 Bf/Acre/Year for CE and 48 Bf/Acre/Year for EA. Inventory (standing volume) started at 3.9 BBF in period zero, and increased to 15.7 BBF by the end of period 20.

5.2.1.2 BIO GROSS – Maximum Biological Potential

The purpose of this model run was to determine the highest biologically achievable harvest level by removing all constraints except NDY. The harvest volume was also inclusive of leave trees. I.e., the over-story component associated with the even-aged pathways, which is normally left standing after the regeneration harvest, was included with the harvest volume.

(I.e. harvested). The resulting model returned a sustainable harvest of 80.3 MMBF/Year. Inventory decreased over time to 2.9 BBF. On this run, 6,545 acres were allocated to no-management, while 722,833 acres received a pathway with active management. The model had the option to schedule these acres, but elected not to do so since they did not contribute to an increase in the harvest level.

5.2.1.3 BIO NET – Leave Tree and Snag Requirements

The purpose of this model run was to show the impact of the leave trees, which include snags, snag recruits, and other un-harvested over-story trees, on the biological potential. It is exactly the same as BIO GROSS, with exception that the leave tree volumes are removed from the sustainable harvest level. As such it shows the drop in harvest volume attributable to the leave trees. The resulting model returned a sustainable harvest of 69.0 MMBF/Year, a decrease of 14.1%. Inventory decreased over time to 3.4 BBF. As with BIO GROSS, this run allocated 6,545 acres to no-management, while 722,833 acres received a pathway with active management.

5.2.1.4 DEF – Deferrals

The purpose of this model run was to show the impact of the deferred acres on the sustainable harvest level. All deferred acres are limited to grow-only pathways, resulting in 116,107 being removed from managed pathways. The resulting sustainable harvest level was 63.0 MMBF/Year, a decrease of 8.7%. Inventory increased over time to 4.7 BBF. On this run, 120,994 acres were assigned to no-management, while 608,384 acres received a pathway with active management. These no management acres resulted from the deferred acres that were added to thus run, plus a portion of the no management acres that were carried over from the BIO GROSS and BIO NET runs.

5.2.1.5 RMZ/UMZ- Riparian and Unique Management Zone Constraints

This run showed the impact of RMZ and UMZ acres on the sustainable harvest level. The constraints associated with these acres call for no-management on the RMZ acres, and no even-aged management on the UMZ acres. The RMZ acres totaled 29,514, while the UMZ acres totaled 2,077. The resulting sustainable harvest level was 59.7 MMBF/Year, a decrease of 5.3%. Inventory increased over time to 5.3 BBF. On this run, 145,792 acres were assigned to no-management, while 583,586 acres received a pathway with active management. These no management acres resulted from the RMZ acres that were added to thus run, plus the no management acres that were carried over from the DEF run.

5.2.1.6 OG – Old Growth Constraints

For the OG constraint, existing stand conditions in some Units were below the targeted amounts of 8% for NW and SW or 4% for CE, due to the effects of past disturbances including wildfires, forest insect and disease outbreaks, and past timber management. In those Units, the model was initially unable to meet the constraint requirement over the 200-year planning horizon; however, with no management applied (grow only) the model was able to meet the constraint requirements for those Units after a certain number of periods. To solve this issue, the old growth constraint for those units was adjusted to require that each Unit currently below the intended target percentage meet that percentage by the same period that the grow only model run was able to meet the constraint (i.e.—if the grow only model run met the percentage requirement in period five, the constraint was adjusted to require the Unit to meet the constraint by period five (See Table 15). This required the model to maintain existing old growth in accordance with the management regimes applicable to old growth stands while also assigning management pathways to non-old growth stands that facilitated their development into old growth in an amount sufficient to meet the Unit's percentage requirement by the period required, which ensured that the intended old growth amount was met as quickly as possible.

Table 15: Adjusted Periods for OG Constraints

OG Unit Constraint	Start Period
KAL and PLN	5
ANA	3
CLW, HAM and MSO	5
BOZ	5
CON	9
HEL	6

This run showed the impact of constraints associated with OG, which called for 8% OG on each unit in the NW and SW land offices, and 4% OG on each unit in the CE land office. As mentioned above, this constraint was adjusted to accommodate the fact that the starting point for some constraints were below the required level. The target acres for each unit are shown in Table 16. The resulting sustainable harvest level was 59.4 MMBF/Year, a decrease of 0.4%. Inventory increased over time to 5.2 BBF. On this run, 145,726 acres were assigned to no-management, while 583,652 acres received a pathway with active management. No additional acres were forced into no management on this run, so most of these acres were carried over from the RMZ/UMZ run. The slight increase in managed acres is attributable to the fact that this model run (OG) was more constrained than the previous RMZ/UMZ run, which forced the model to pull into solution those acres which it previously had the option to exclude (See BIO GROSS in section 5.2.1.2).

Table 16: Old Growth Target Acres per Unit

Land Office	Unit	Target Acres
CE	BOZ	732
	CON	158
	DIL	1,123
	HEL	2,253
NW	KAL	4,061
	LIB	2,352
	PLN	3,979
	STW	8,966
	SWN	4,167
SW	ANA	2,121
	CLW	5,339
	HAM	1,846
	MSO	6,533

5.2.1.7 HELI – Helicopter Harvest Constraint

The helicopter harvest constraint limited the volume that can be harvested from helicopter acres, by capping the helicopter harvest volume to 2% of the total harvest volume within any given time period (exclusive of helicopter volume). The helicopter volume is seen as opportunistic, and it is therefore excluded from the NDY constraint, but included in the objective function. By constraining the helicopter volume it enables more non-helicopter acres to participate in the objective function, resulting in a slight increase in the sustainable harvest level when this constraint is switched on. The resulting sustainable harvest level was therefore 59.5 MMBF/Year, an increase of 0.1%. The associated threshold helicopter harvest volume was 1.11 MMBF/Year (I.e., when available, the model could harvest a maximum of 1.11 MMBF/Year from helicopter acres). Inventory increased over time to 5.3 BBF. On this run, 145,961 acres were assigned to no-management, while 583,417 acres received a pathway with active management. No additional acres were forced into no management on this run, so most of these acres were carried over from the OG run. The slight change in no management acres can be attributed to more of the optional acres being pulled into solution (See BIO GROSS in section 5.2.1.2).

5.2.1.8 EAR – Even-Aged Harvest Constraint

The even-aged harvest constraint showed the impact of the desired future condition on the harvest level. This constraint limited the number of acres that could be managed under CCRX, STRX, SWRX, and UERX, in accordance with predefined goals aimed at applying appropriate silvicultural treatments in reasonable proportions by cover type. Table 17 shows the constraint levels used. The resulting sustainable harvest level was 58.6 MMBF/Year, a decrease of 1.5%. Inventory increased over time to 5.6 BBF. On this run, 145,843 acres were assigned to no-management, while 583,535 acres received a pathway with active management. No additional acres were forced into no management on this run, so most of these acres were carried over from the HELI run. The slight change in no management acres can be attributed to more of the optional acres being pulled into solution (See BIO GROSS in section 5.2.1.2).

Table 17: Threshold Acres for EAR Constraint

Rx Group	Threshold Acres
CCRX	59,375
STRX	204,332
SWRX	173,287
UERX	292,652
Total	**729,379**

5.2.1.9 SEN – Sensitive Watershed Constraint

The purpose of this run was to show the impact of the sensitive watershed constraints, which limited the amount of acres less than age 40 years to 36% of each watershed's acres. The target acres for each watershed is shown in Table 18. The resulting sustainable harvest level was 58.5 MMBF/Year, a decrease of 0.1%. Inventory increased over time to 5.6 BBF. In this run, 145,670 acres were assigned to no-management, while 583,708 acres received a pathway with active management. No additional acres were forced into no management on this run, so most of these acres were carried over from the EAR run. The slight change in no management acres can be attributed to more of the optional acres being pulled into solution (See BIO GROSS in section 5.2.1.2).

Table 18: Sensitive Watershed Target Acres

Watershed	Target Acres
Upper Whitefish (UPWH)	9,523
South Fork Lost-Soup (SFLS)	6,337
Porcupine-Woodward (POWO)	6,901
Lion Creek (LICR)	1,049
Lazy Creek (LACR)	2,976
Goat Creek (GOCR)	4,202
Stillwater-Coal Creek (STCC)	4,771

5.2.1.10 GZB –Grizzly Bear Habitat Constraints

This run showed the impact of the Grizzly Bear constraints on the harvest level. These constraints comprised of the Grizzly Bear Visual Buffer constraints, and the Grizzly Bear Core constraints. The visual buffer constraint called for no even-aged management in established buffers within grizzly bear habitat, while the Core constraint called for no management. The visual buffer acres totaled 6,933, while the Core acres totaled 34,363 of commercial forest. The resulting sustainable harvest level was 55.9 MMBF/Year, a decrease of 4.5%. Inventory increased over time to 6.1 BBF. On this run, 167,993 acres were assigned to no-management, while 561,385 acres received a pathway with active management. These no management acres resulted from the Grizzly Bear Core acres that were added to this run, plus the no management acres that were carried over from the SEN run.

5.2.1.11 LMA – Canada Lynx Management Area Constraints

The purpose of this run was to show the impact on the harvest level of HCP constraints applied within the Lynx Management Areas. This constraint consisted of various subsets of constraints, each dealing with a different aspect of Lynx habitat (LM1, LM2, LM31, and ITP). The acreage thresholds associated with these constraints are shown in Table 19. The resulting sustainable harvest level was 55.9 MMBF/Year, a decrease of 0.1%. Inventory increased over time to 6.1 BBF. In this run, 166,035 acres were assigned to no-management, while 563,343 acres received a pathway with active management. The change in the no management acres from the GZB run was small, since no additional acres were forced into no management on this run.

Table 19: LMA Constraint Targets

LMA	**LM1** - Retain 65% Suitable Habitat	**LM2** - Restrict Suitable Habitat Conversion to 15% per Decade	**LM31** - Retain 20% Winter Foraging Habitat	**ITP** - Pre-Commercial Thinning Cap
Coal Creek (CC)	9,545	2,203	2,937	1,165
Garnet (GA)	5,641	1,302	1,736	689
Stillwater East (SE)	21,374	5,016	6,687	2,653
Seeley Lake (SLA)	7,911	1,826	2,434	966
Stillwater West (SW)	24,919	5,750	7,667	3,042
Swan	33,668	7,770	10,359	3,485

5.2.1.12 POT – Suitable Canada Lynx Habitat Constraint on Scattered Lands

The purpose of this run was to show the impact on the harvest level of the requirement to maintain suitable lynx habitat on all potential lynx habitat land. This constraint called for maintaining adequate threshold cover amounts across 65% of total potential habitat acres, at a land office level. The target acres for each land office associated with this constraint are shown in Table 20. The resulting sustainable harvest level was 55.8 MMBF/Year, a decrease of 0.2%. Inventory increased over time to 6.2 BBF. In this run, 166,927 acres were assigned to no-management, while 562,451 acres received a pathway with active management. The change in the no management acres from the LMA run was small, since no additional acres were forced into no management on this run.

Table 20: Suitable Lynx Habitat Target Acres

Land Office	Target Acres
CE	36,713
EA	4,209
NW	49,848
SW	23,928

5.2.1.13 EAG – Bald Eagle Habitat Constraint

For the bald eagle constraint, the model was unable to meet the threshold requirement of 6,765 acres. This was due to the fact that some stands did not meet the minimum requirement of 60 ft^2/acre of BA from the onset (period 0), despite being classified as bald eagle habitat; while others never grew beyond 60 ft^2/acre of BA. The primary cause of this is that the model utilized strata level yield tables, which represented the average condition of all stands in the strata (I.e., the actual stand probably achieved the threshold value, and hence the fact that it was classified as bald eagle habitat). With no management (grow only), the model was able to meet the constraint on a statewide basis by period four, so in order to provide the model with a workable solution that incorporated management, the starting period for the constraint was changed to period four and the threshold was reduced to 6,700 acres to maintain the greatest level of constraint possible.

The results of this run showed the impact of the bald eagle constraints on the harvest level. This constraint called for habitat in eagle nesting and primary use areas to be maintained, by only assigning uneven-aged moist-site and wet-site pathways. The resulting sustainable harvest level was 55.5 MMBF/Year, a decrease of 0.5%. Inventory increased over time to 6.2 BBF. In this run, 167,768 acres were assigned to no-management, while 561,610 acres received a pathway with active management. The change in the no management acres from the POT run was small, since no additional acres were forced into no management on this run.

5.2.2 Scenario 2 – Unconstrained Grizzly Bear Core

The state-level model with the Grizzly Bear Core constraint off (Core is unconstrained and available for management) was run in a step-wise manner, incrementally adding constraints to the model to assess their impact. The objective of these model runs was to simulate management of Stillwater Grizzly Bear Core habitat under the DNRC HCP. This was attained by switching off the Core constraint and running the model with 18,043 of the 34,363 commercial forest acres of Grizzly Bear Core in model solution. The remaining 16,321 commercial forest acres in Core were already deferred for other reasons (see section 5.2.1).

In this section only the results for the GZB, LMA, POT and EAG constraints will be reported, since the rest are identical to the runs with the Core constraint on (see section 5.2.1). The incremental steps are discussed and illustrated in the following sections and Figure 3. Overall results showed that a harvest level of 57.8 MMBF/Year can be maintained. With all constraints applied (EAG model), a total of 582,944 acres were allocated to management regimes (included in solution), and 146,434 acres were excluded from management.

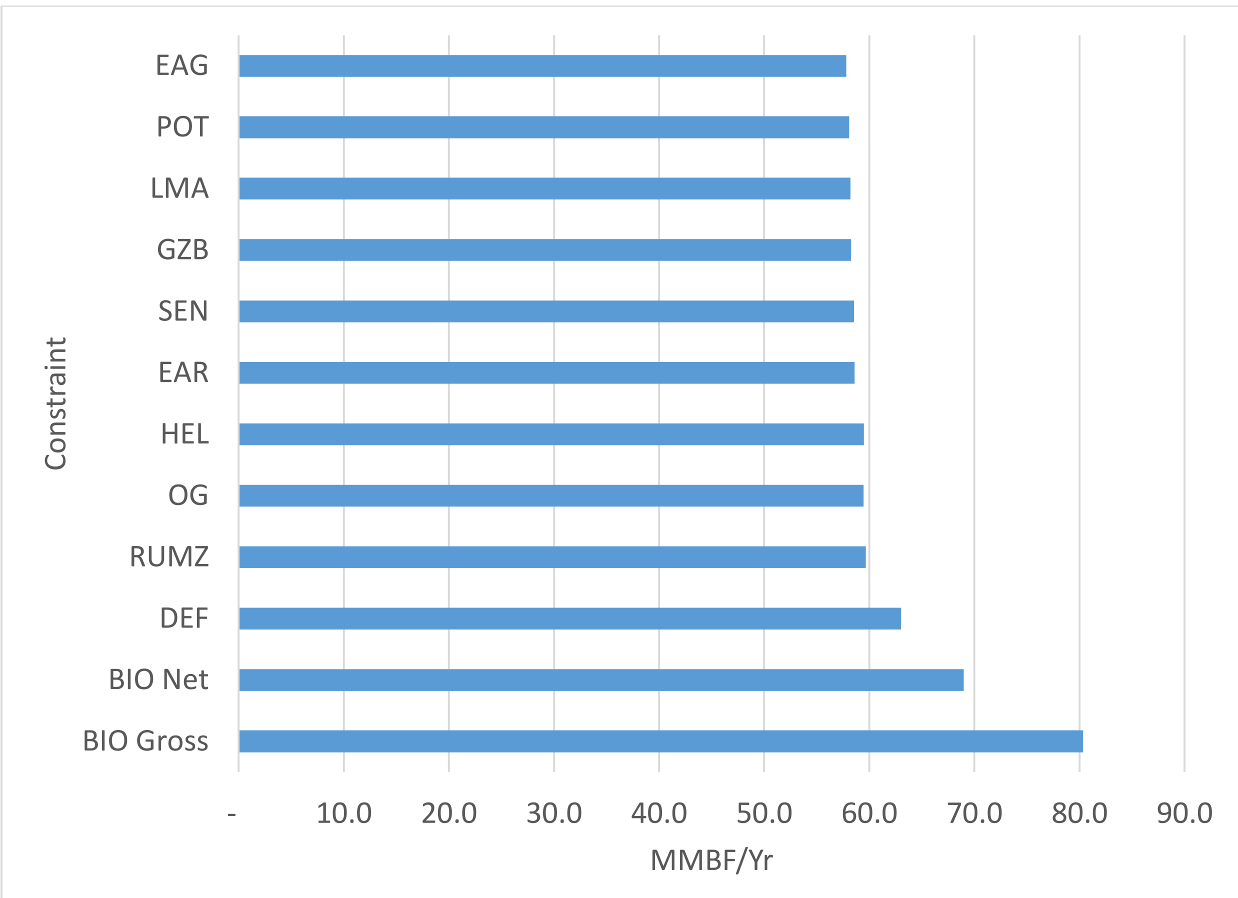


Figure 3: State – Wide Sequential Results with Grizzly Bear Core Unconstrained

5.2.2.1 GZB – Grizzly Bear Habitat Constraints

This run showed the impact of the Grizzly Bear constraints on the harvest level. These constraints comprised of the Grizzly Bear Visual Buffer constraints only. The resulting sustainable harvest level was 58.3 MMBF/Year, a decrease of 0.5% from the sensitive watersheds level. Inventory increased over time to 5.6 BBF. In this run, 146,545 acres were assigned to no-management, while 582,833 acres received a pathway with active management. The change in the no management acres from the SEN run was small, since no additional acres were forced into no management on this run.

5.2.2.2 LMA – Canada Lynx Management Area Constraints

The purpose of this run was to show the impact of the Lynx Management Areas on the harvest level. This constraint consisted of various subsets of constraints, each dealing with a different aspect of Lynx habitat (LM1, LM2, LM31, and ITP). The resulting sustainable harvest level was 58.2 MMBF/Year, a decrease of 0.1%. Inventory increased over time to 5.6 BBF. In this run, 144,492 acres were assigned to no-management, while 584,886 acres received a pathway with active management. The change in the no management acres from the GZB run was small, since no additional acres were forced into no management on this run.

5.2.2.3 POT – Suitable Canada Lynx Habitat Constraint for Scattered Lands

The purpose of this run was to show the impact of the potential Lynx habitat constraint on the harvest level. This constraint called for maintaining 65% of potential habitat acres under adequate cover. The resulting sustainable harvest level was 58.1 MMBF/Year, a decrease of 0.2%. Inventory increased over time to 5.6 BBF. In this run, 145,224 acres were assigned to no-management, while 584,154 acres received a pathway with active management. The change in the no management acres from the LMA run was small, since no additional acres were forced into no management on this run.

5.2.2.4 EAG – Bald Eagle Habitat Constraint

The results of this run showed the impact of the eagle constraints on the harvest level. This constraint called for habitat in eagle nesting areas to be maintained, by only assigning uneven-aged moist-site and wet-site pathways. The resulting sustainable harvest level was 57.8 MMBF/Year, a decrease of 0.5%. Inventory increased over time to 5.7 BBF. In this run, 146,434 acres were assigned to no-management, while 582,944 acres received a pathway with active management. The change in the no management acres from the POT run was small, since no additional acres were forced into no management on this run.

5.2.3 Scenario 3 – NEW – Constrained Grizzly Bear Security Zones

This scenario constrained management within the Grizzly Bear Security Zones, which encompasses a total area of 22,007 acres of the Stillwater Unit (of which 21,966 acres are commercial forest). Under this model scenario, the Security Zones are not available for harvest. However, the net reduction in manageable commercial acres is only 8,013 acres, since 7,197 acres within the Security Zones were already deferred for other reasons, while 6,394 acres of helicopter and 363 acres of RMZ were not available for management.

The model was run at a statewide level and in a step-wise manner, incrementally adding constraints to the model to assess their impact. The objective of these model runs was to simulate management of Stillwater Grizzly Bear Security Zones under the recently negotiated settlement agreement. In this section only the results for the GZB, LMA, POT and EAG constraints will be reported, since the rest are identical to the runs with the Core constraint on (see section 5.2.1). The incremental steps are discussed and illustrated in the following sections and Figure 4. Overall results showed that a harvest level of 56.9 MMBF/Year can be maintained. With all constraints applied (EAG model), a total of 570,510 acres were allocated to management regimes (included in solution), and 158,869 acres were excluded from management.

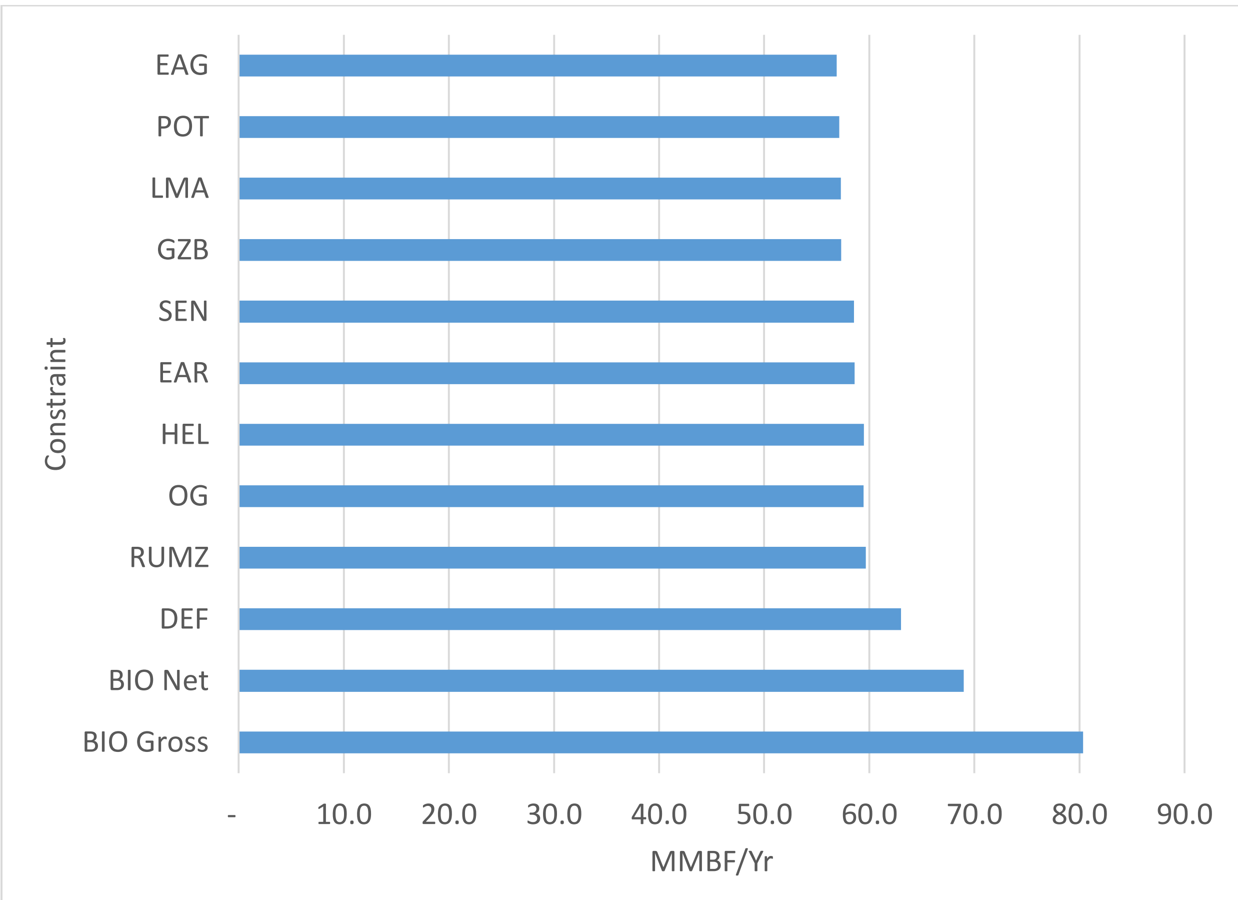


Figure 4: State – Wide Sequential Results with Grizzly Security Zones Constrained

5.2.3.1 GZB – Grizzly Bear Habitat Constraints

This run showed the impact of the Grizzly Bear constraints on the harvest level. These constraints comprised of the Grizzly Bear Visual Buffer constraints, and the Grizzly Bear Security Zones constraints. The visual buffer constraint called for no even-aged management in established buffers within grizzly bear habitat, while the Security Zones constraint called for no management. The visual buffer acres totaled 6,933, while the Security Zone acres included 21,966 acres of commercial forest. The resulting sustainable harvest level was 57.3 MMBF/Year, a decrease of 2.1% when compared to the SEN constraint. Inventory increased over time to 5.9 BBF. On this run, 155,835 acres were assigned to no-management, while 573,544 acres received a pathway with active management. These no management acres resulted from the Grizzly Bear Security Zone acres that were added to this run, plus the no management acres that were carried over from the SEN run.

5.2.3.2 LMA – Canada Lynx Management Area Constraints

The purpose of this run was to show the impact of the Lynx Management Areas on the harvest level. This constraint consisted of various subsets of constraints, each dealing with a different aspect of Lynx habitat (LM1, LM2, LM31, and ITP). The resulting sustainable harvest level was 57.3 MMBF/Year, a decrease of 0.1%. Inventory increased over time to 5.9 BBF. In this run, 156,848 acres were assigned to no-management, while 572,531 acres received a pathway with active management. The change in the no management acres from the GZB run was small, since no additional acres were forced into no management on this run.

5.2.3.3 POT – Suitable Canada Lynx Habitat Constraint for Scattered Lands

The purpose of this run was to show the impact of the potential lynx habitat constraint on the harvest level. This constraint called for maintaining 65% of potential habitat acres under adequate cover. The resulting sustainable harvest level was 57.1 MMBF/Year, a decrease of 0.4%. Inventory increased over time to 5.9 BBF. In this run, 156,591 acres were assigned to no-management, while 572,788 acres received a pathway with active management. The change in the no management acres from the LMA run was small, since no additional acres were forced into no management on this run.

5.2.3.4 EAG – Bald Eagle Habitat Constraint

The results of this run showed the impact of the eagle constraints on the harvest level. This constraint called for habitat in eagle nesting areas to be maintained, by only assigning uneven-aged moist-site and wet-site pathways. The resulting sustainable harvest level was 56.9 MMBF/Year, a decrease of 0.4%. Inventory increased over time to 6.0 BBF. In this run, 158,869 acres were assigned to no-management, while 570,511 acres received a pathway with active management. The change in the no management acres from the POT run was small, since no additional acres were forced into no management on this run.

5.2.4 Scenario 4 – Impact of Acquired Lands

A model run was conducted to determine the impact of the acquired acres on the sustainable yield. For this scenario, the acquired lands were withdrawn from the Unconstrained Grizzly

Bear Core model (Section 5.2.2), resulting in an annual sustainable harvest level of 53.2 MMBF and inferring that the addition of those lands contributes 4.6 MMBF to the annual sustainable yield.

6 Recommendations for Future Calculations

Following the 2004 sustainable yield calculation, the DNRC embarked on an initiative to establish an in-house inventory program, which called for tree measurements taken from DNRC land and used cruising methods that targeted the forest conditions found on DNRC land. This process strengthened the conclusions reached from the 2015 sustainable yield calculation, since the inventory data used was more representative of DNRC land. There is however still room for improvement in this program, since the data gathered thus far does not cover all DNRC land, nor does it represent a complete sample of lands measured thus far. It is therefore recommended that the DNRC conduct tree measurements in those areas that have been omitted thus far, like the eastern land offices. Also, for strata that have been measured to date, collect additional plot data to strengthen future inventory calculations. In this regard it would be beneficial to establish an annual cruising plan, which targets specific stands for incorporation into the inventory calculation.

It was also observed that considerable improvements in the SLI database had been made since the 2004 sustainable yield calculation. There are, however, still improvements that could be made to the SLI that would strengthen future calculations. One of these would be to complete the habitat typing for stands missing this information, and also to check the consistency of the existing data for conformance within a given strata. The same is true for stand age and productivity estimates, since they were also heavily relied upon in the modeling process. Stand age is difficult concept to incorporate, since most of the DNRC stands are uneven-aged. It is however important to identify and maintain some form of age estimate or proxy, since it is a critical element in determining the eligibility of a given strata for the management actions within the various models used.

Finally, a large part of the effort in calculating the 2015 sustainable harvest level went towards calibrating the FVS growth and yield models. It is recommended that these calibration efforts be continued and expanded upon in the future, since it forms a critical component of the sustainable yield calculation. So rather than calibrating these models as they are needed, they should be calibrated and tested on an ongoing annual basis as new inventory data (and models) become available. It is also recommended that the DNRC actively engage the publishers of FVS in an effort to improve the performance of these models on DNRC land.

7 MB&G Certification

I certify that to the best of my knowledge and belief that:

- The statement of facts contained in this report is true and correct.
- The reported analyses, opinions, and conclusions are limited only by the reported assumptions and limiting conditions and reflect my personal, unbiased professional analyses, opinions and conclusions.
- We have no present or prospective interest in the resource that is the subject of this report.
- Engagement in this assignment was not contingent upon developing or reporting predetermined results.
- Compensation for completing this assignment is not contingent upon the development or reporting of a predetermined result or direction in result that favors the cause of the client.
- Significant professional assistance was provided to the persons signing this certification as follows: Brian Long, Brandon Vickery and Jessica Burton-Desrocher.

___________________________	___________________________
Hendrik C. Stander	Mark L. Rasmussen
Mason, Bruce & Girard, Inc.	Mason, Bruce & Girard, Inc.

8 Appendix A: Summary of Model Runs

8.1 Unconstrained Grizzly Bear Core Acres

The following charts show selected results from the final LP model run with unconstrained Grizzly Bear Core acres (active management allowed within the Core).

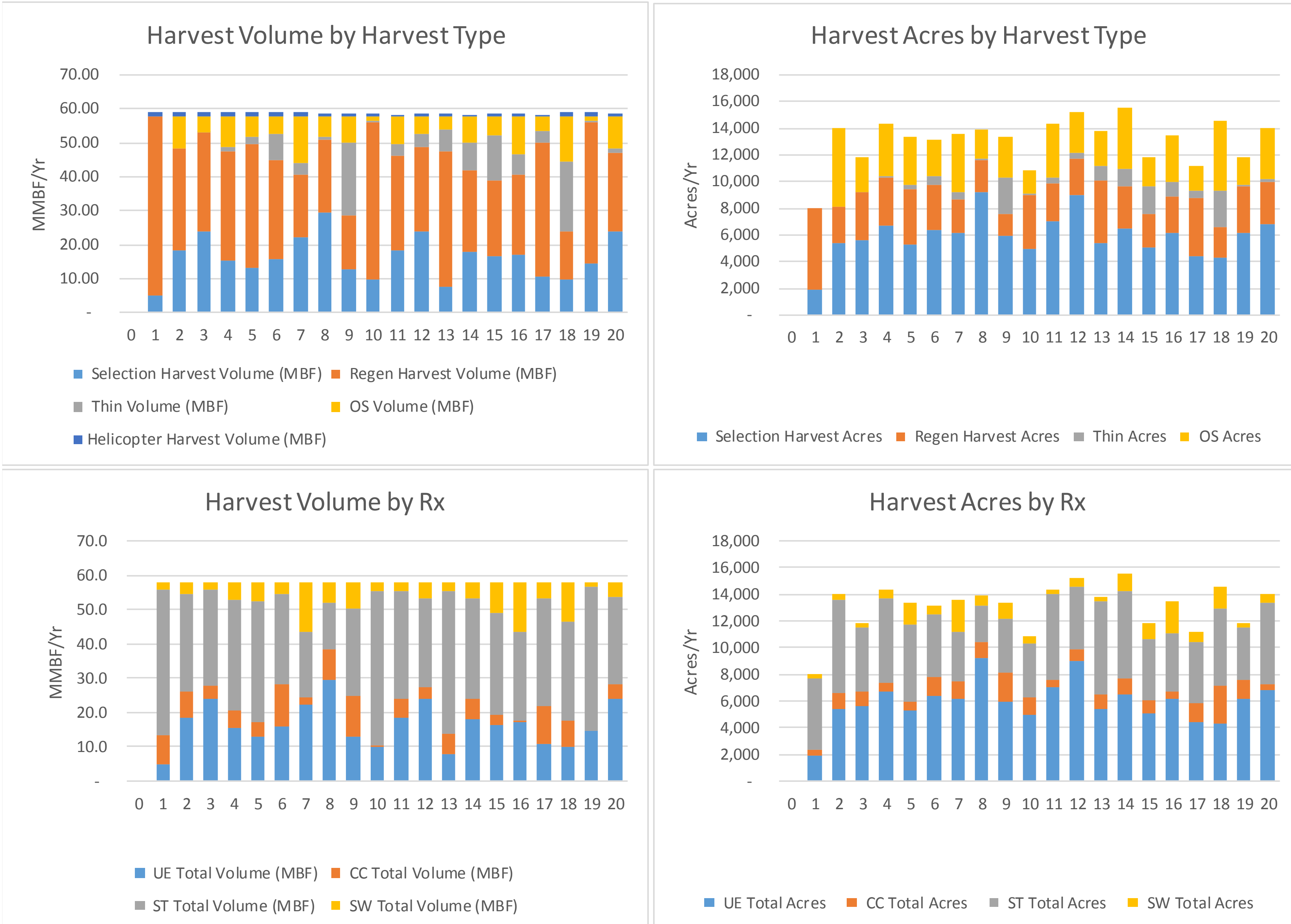
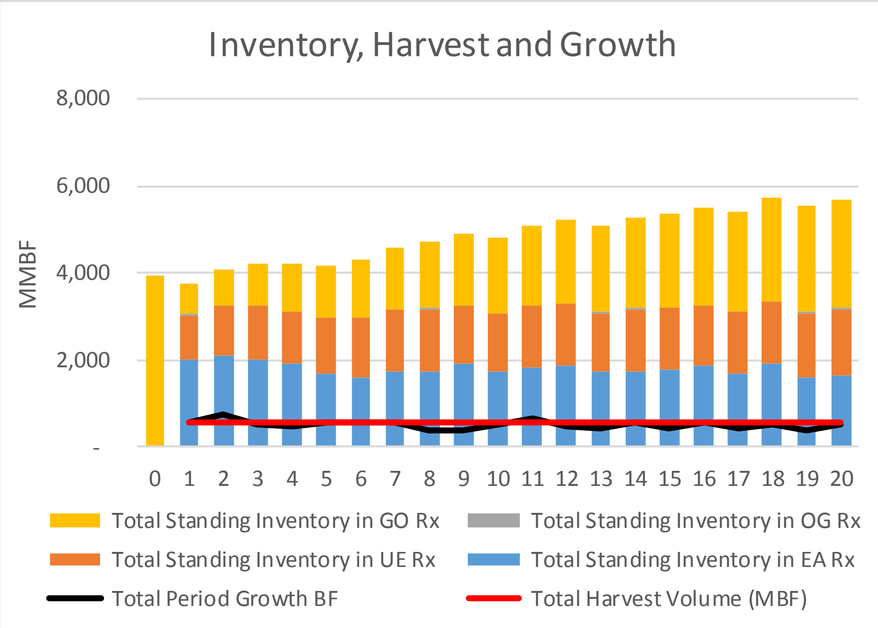


Figure 5: Statewide LP Model Results – Unconstrained Grizzly Bear Core – Page 1



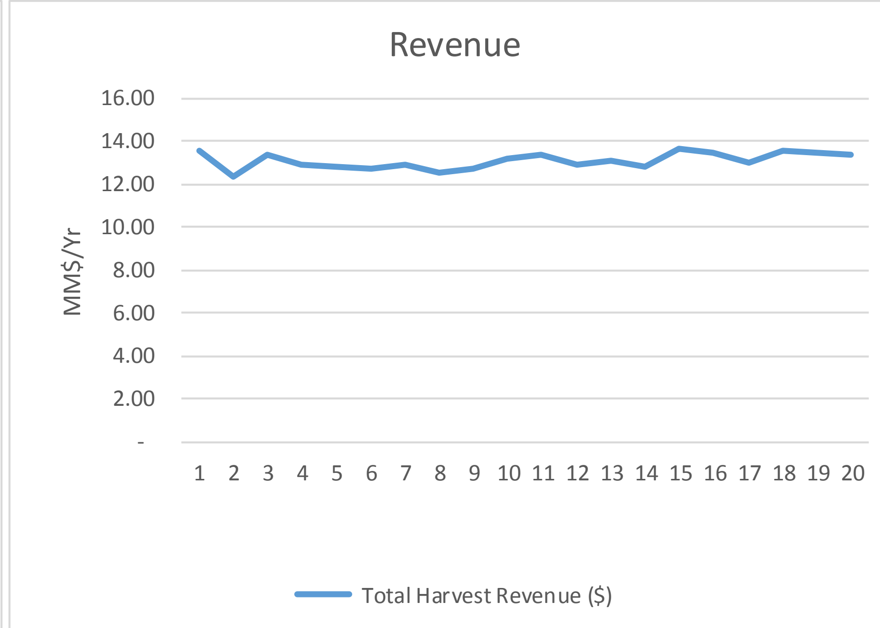
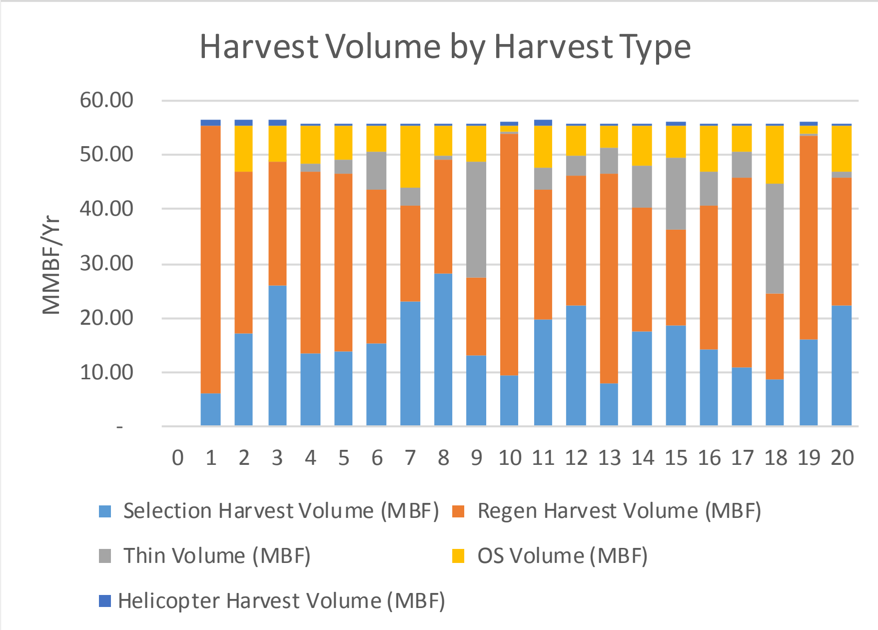
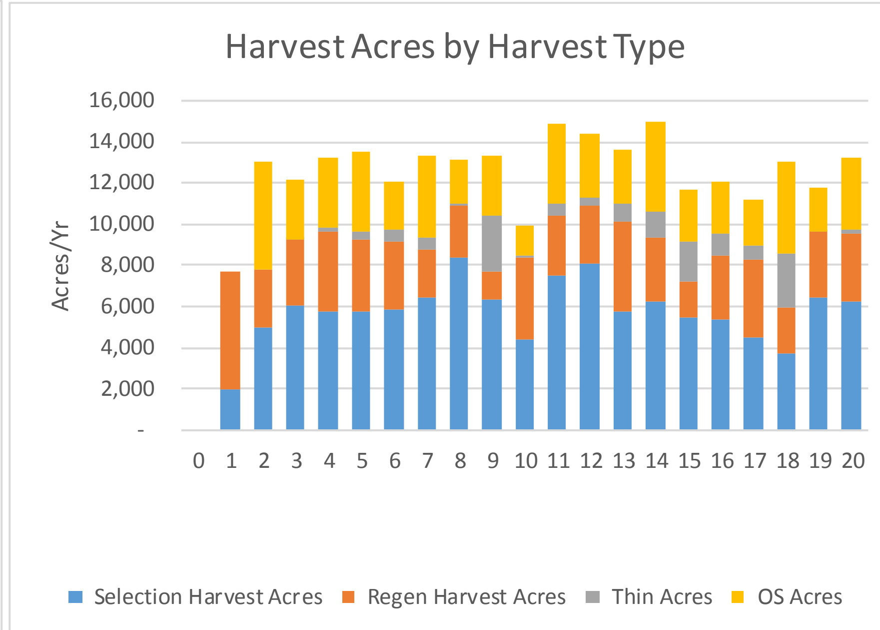


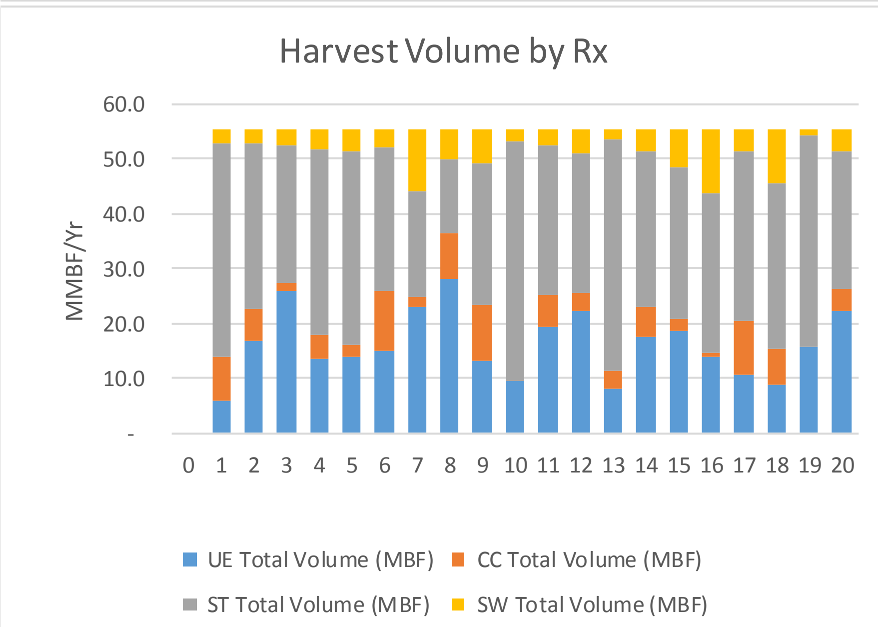
Figure 6: Statewide LP Model Results – Unconstrained Grizzly Bear Core – Page 2

8.2 Constrained Grizzly Bear Core Acres

The following charts show selected results from the final LP model run with constrained Grizzly Bear Core acres (active management not allowed within the Core).







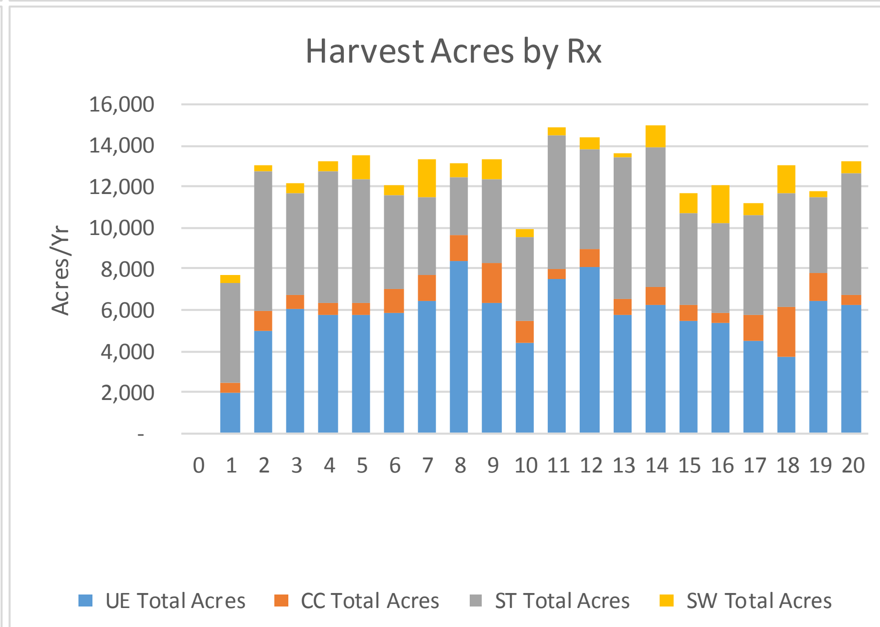
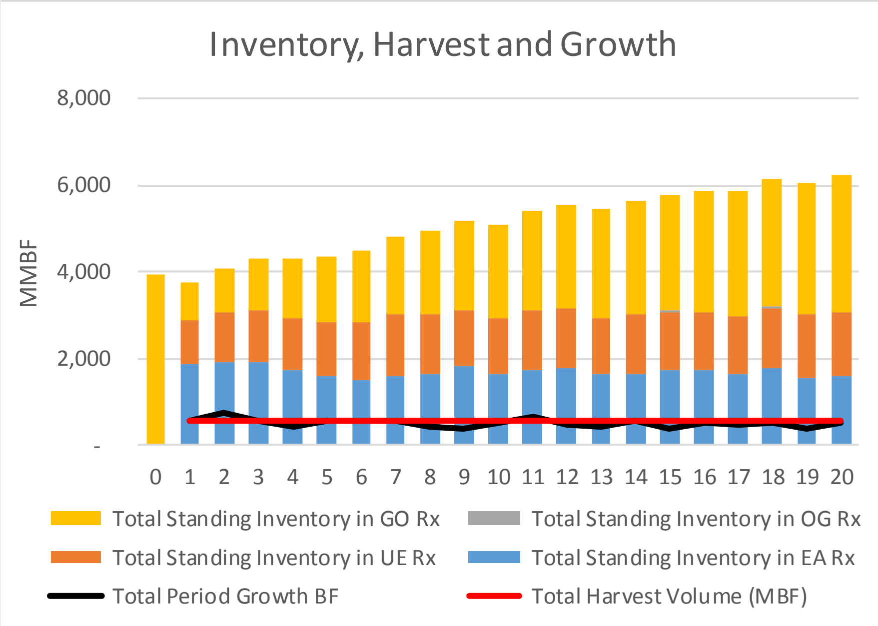


Figure 7: Statewide LP Model Results –Constrained Grizzly Bear Core – Page 1



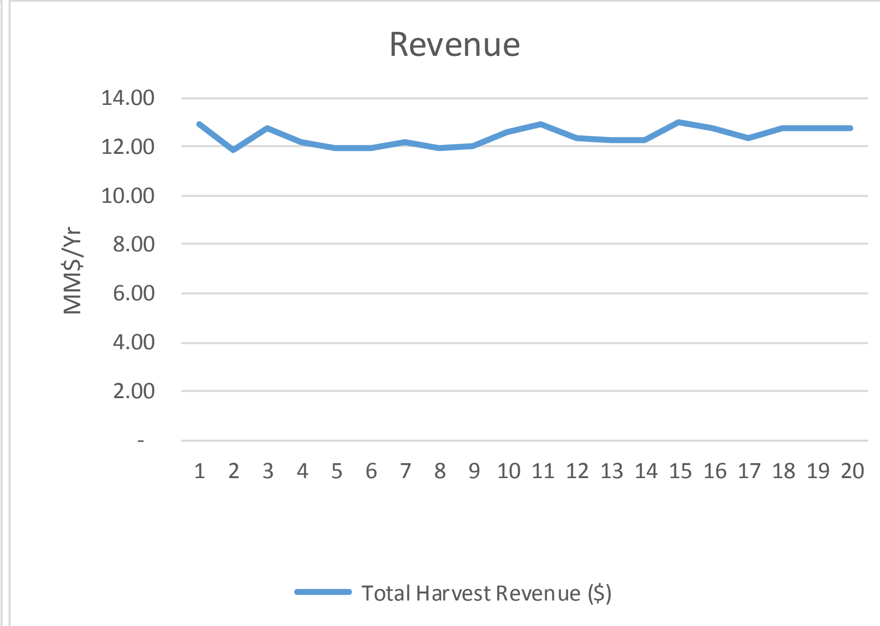
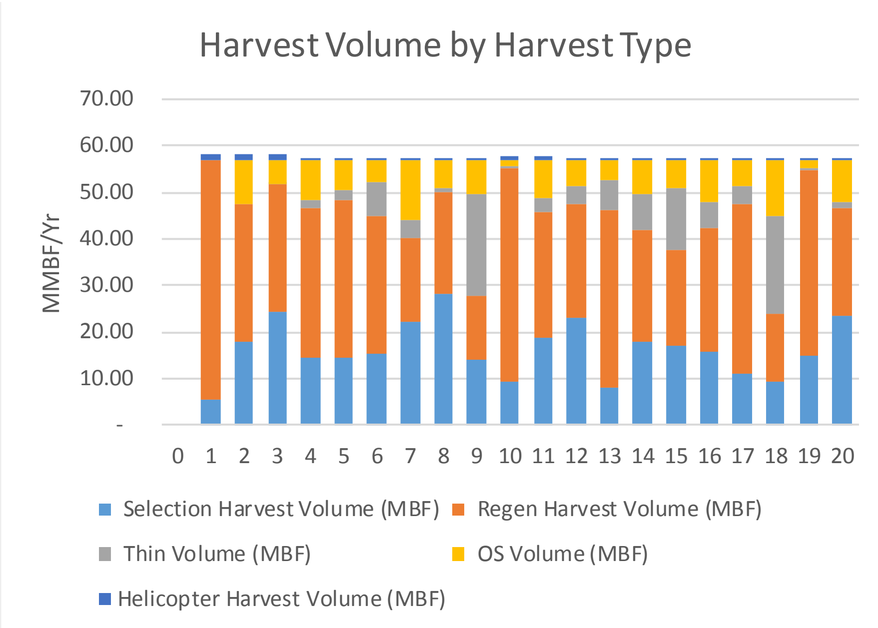
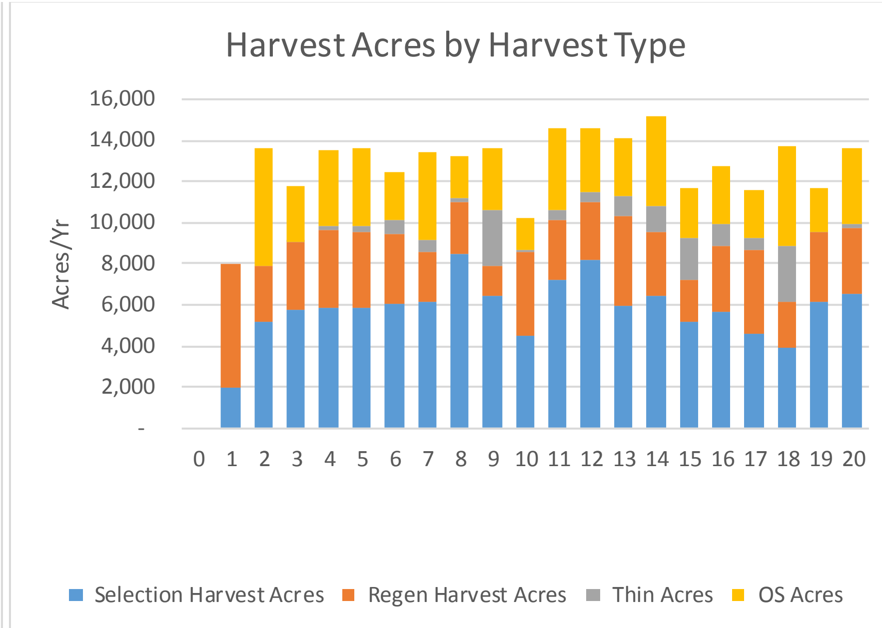


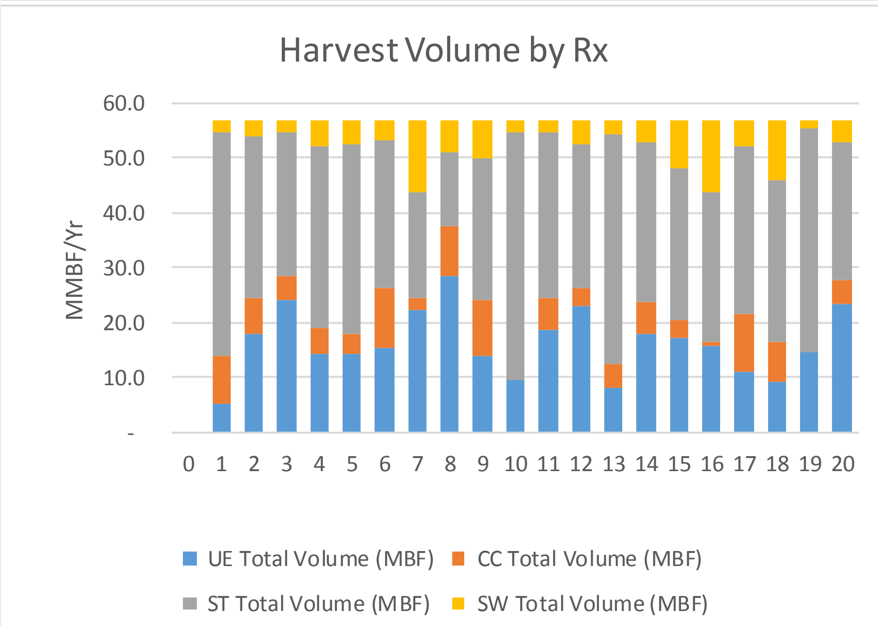
Figure 8: Statewide LP Model Results –Constrained Grizzly Bear Core – Page 2

8.3 Constrained Grizzly Bear Security Zones Acres

The following charts show selected results from the final LP model run with constrained Grizzly Bear Security Zone acres (active management not allowed within the Security Zones).







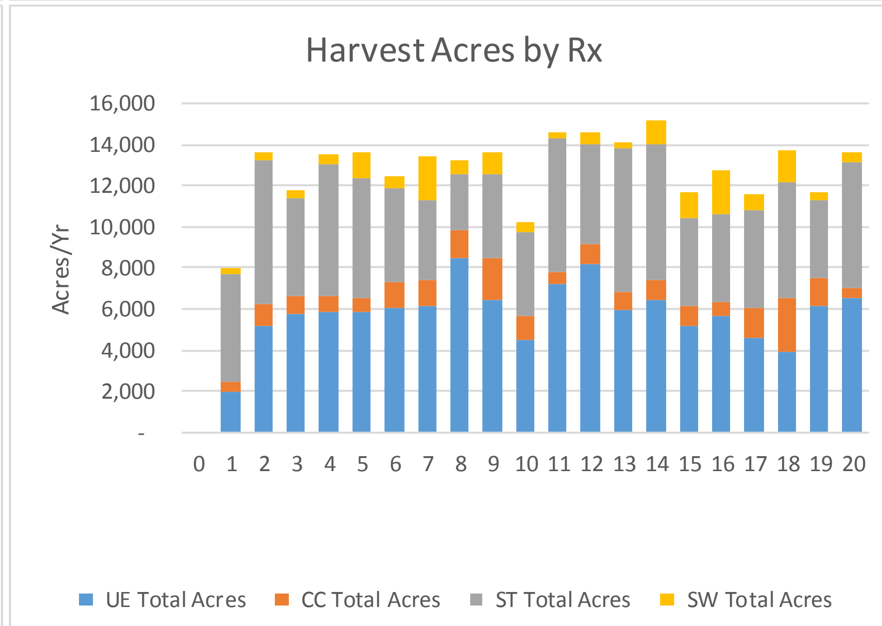


Figure 9: Statewide LP Model Results –Constrained Grizzly Bear Security Zones – Page 1

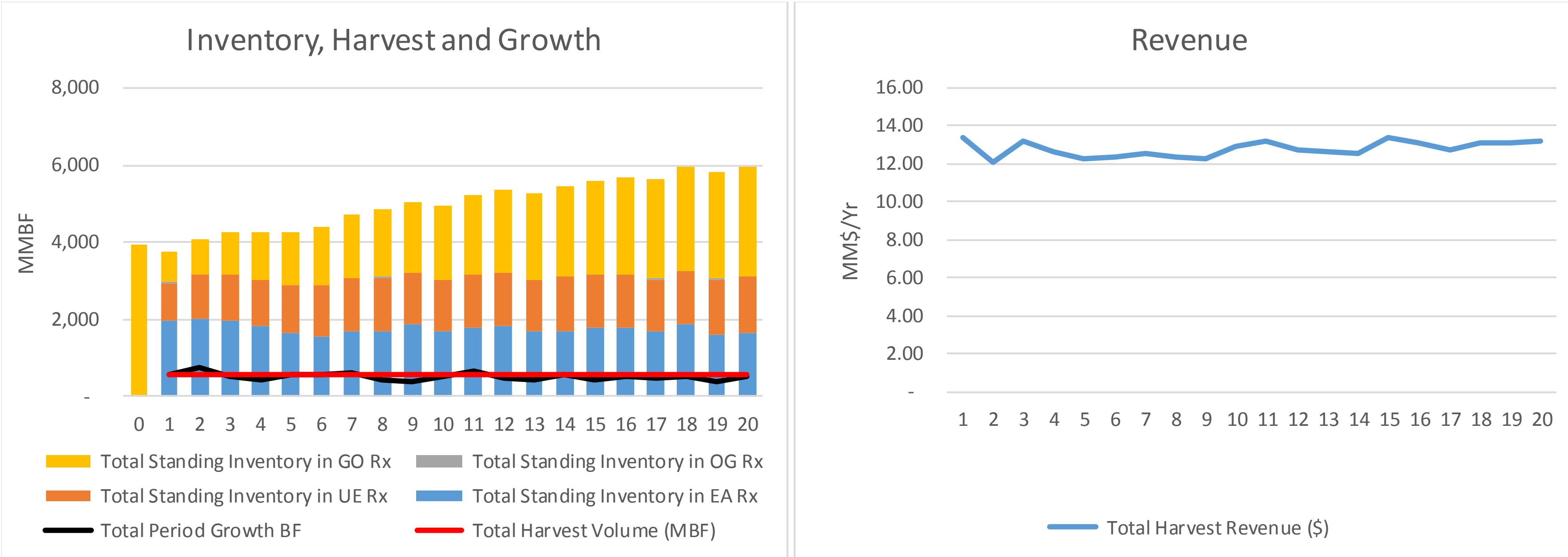


Figure 10: Statewide LP Model Results –Constrained Grizzly Bear Security Zones – Page 2

9 Appendix B: Compatibility Matrix

The following matrix shows the relationship between the various LP model thematic layers and the major management pathway groups

- GORX. Grow only management pathways with no active management or silvicultural treatments.
- CCRX. Even-aged management pathway (EARX) that terminates in a clear-cut regeneration harvest.
- STRX. Even-aged management pathway (EARX) that terminates in a seed-tree regeneration harvest.
- SWRX. Even-aged management pathway (EARX) that terminates in a shelter-wood regeneration harvest.
- UERX. Uneven-aged management pathway with multiple selection harvest.
- OGRX. Old-growth management pathway with multiple selection harvest entries, which aim to maintain old-growth status.

In this table a "?" indicated that the given thematic layer was not limiting with regards to the pathway, while an "N" indicates that only areas coded as not part of the thematic layer could participate in the pathway. Additional details for the land office, species and productivity themes are provided in Appendix D.

Theme	Description	GORX	CCRX	STRX	SWRX	UERX	OGRX
1	Strata ID	?	?	?	?	?	?
2	Land Office	Appendix D	Appendix D	Appendix D	Appendix D	Appendix D	Appendix D
3	Unit	?	?	?	?	?	?
4	Species	Appendix D	Appendix D	Appendix D	Appendix D	Appendix D	Appendix D
5	Size	?	?	?	?	?	?
6	Stocking	?	?	?	?	?	?
7	Productivity Class	Appendix D	Appendix D	Appendix D	Appendix D	Appendix D	Appendix D
8	Start Age	?	?	?	?	?	?
9	Deferred	?	N	N	N	N	N
10	Rx	?	?	?	?	?	?
11	Timing	?	?	?	?	?	?
12	Rotation	?	?	?	?	?	?
13	Sensitive Watersheds	?	?	?	?	?	?
14	UMZ	?	N	N	N	?	?
15	Helicopter	?	?	?	?	?	?
16	RMZ	?	N	N	N	N	N
17	GZB Visual Buffer	?	N	N	N	?	?
18	GZB Core Class A	?	?	?	?	?	?
19	GZB Security Core	?	N	N	N	N	N
20	GZB Subunits	?	?	?	?	?	?
21	LMA	?	?	?	?	?	?
22	Potential Lynx Habitat	?	?	?	?	?	?
23	Eagle	?	N	N	N	?	?
24	OG Recruitment	?	?	?	?	?	?
25	OG Current	?	?	?	?	?	?

10 Appendix C: Acres in the Forest Management Model

The following tables show the acres present in various thematic layers, and how the acres were classified within each. The thematic layer represented in each table is labeled in the top right corner of each table. The data within each table is organized as cross-tabulations, with thematic values in the rows and land management unit in the columns (except for the first table which has land office in the columns).

The table "Unit Acres" contains a cross-tabulation of management unit acres by land office. Table 21 shows the various codes used for unit and land office:

Table 21: Key to Codes for Land Office and Unit

Land Office	Name
CE	Central
EA	Eastern
NW	North-Western
SW	South-Western

Unit	Name
ANA	Anaconda
BIL	Billings
BOZ	Bozeman
CLW	Clearwater
CON	Conrad
DIL	Dillon
GLA	Glasgow
HAM	Hamilton
HAV	Havre
HEL	Helena
KAL	Kalispell
LEW	Lewiston
LIB	Libby
MIL	Miles City
MSO	Missoula
PLN	Plains
STW	Stillwater
SWN	Swan

The thematic codes use in the "Strata Acres" table consists of three components, namely species (vegetation type), size class and stocking. The code "AF7M" therefore represents the strata for Subalpine Fir (AF) species, seeds & saplings size class (7), and moderate stocking (M). In some cases species is represented by a single digit, while size and stocking are always represented by a single digit. The old-growth strata (W1, W3, W4 and W6) do not follow this classification scheme, and are therefore only represented by their two digit codes. Please refer to section 4.3.5 for a definition of the old growth codes. Table 22 shows the various codes used for species, size and stocking:

Table 22: Key to Codes for Species, Size and Stocking

Species	Name
AF	Subalpine Fir
C	Western Redcedar
D	Douglas-fir
DL	Douglas-fir/Larch
GF	Grand Fir
L	Western Larch
LP	Lodgepole Pine
MC	Mixed Conifer
NS	Non-Stocked
P	Ponderosa Pine
S	Engelmann Spruce
WH	Western Hemlock
WP	Western White Pine

Size	Name
6	Non-Stocked
7	Seeds/Saplings
8	Pole-Timber
9	Saw-Timber

Stocking	Name
N	Non-Stocked
P	Poor
M	Moderate
W	Well

Some thematic layers were labeled with either a “yes” (Y) or “no” (N) value to indicate whether a given acre was part of the constraint or not. Therefore, in the tables below a row value of “In (Y)” was used to flag the acres that were part of the thematic layer, while “Out (N)” was used to flag the acres outside of the thematic layer. For instance, in the Deferred Acres table, the acres associated with the “In (Y)” row were deferred, while the acres associated with the “Out (N)” row were not deferred.

Finally, the following codes in Table 23 were used to identify acres in sensitive watersheds and lynx management areas (LMA).

Table 23: Key to Codes for Sensitive Watersheds and LMA’s

Sensitive Watershed	Name
(UPWH)	Upper Whitefish
(SFLS)	South Fork Lost-Soup
(POWO)	Porcupine-Woodward
(LICR)	Lion Creek
(LACR)	Lazy Creek
(GOCR)	Goat Creek
(STCC)	Stillwater-Coal Creek

LMA	Name
(CC)	Coal Creek
(GA)	Garnet
(SE)	Stillwater East
(SLA)	Seeley Lake
(SW)	Stillwater West
Swan	Swan

Unit Acres	CE	EA	NW	SW	
ANA				26,514	
BIL		50,681			
BOZ	18,297				
CLW				66,735	
CON	3,955				
DIL	28,082				
GLA		4,737			
HAM				23,075	
HAV		4,417			
HEL	56,326				
KAL			50,767		
LEW		30,106			
LIB			29,397		
MIL		40,717			
MSO				81,668	
PLN			49,743		
STW			112,076		
SWN			52,086		
	106,660	**130,658**	**294,068**	**197,992**	**729,379**

Strata Acres	ANA	BIL	BOZ	CLW	CON	DIL	GLA	HAM	HAV	HEL	KAL	LEW	LIB	MIL	MSO	PLN	STW	SWN	Total
AF7M				8							61						1,147	96	1,312
AF7P						9				17							269	34	329
AF7W	55														62		1,952		2,068
AF8M	7		56			66				52	27				27		808	233	1,277
AF8P			80			344				39							372	254	1,089
AF8W			31	17		77									173		811	242	1,352
AF9M	22		977	49		633				35	44				148	68	3,253	488	5,717
AF9P	20		297	65		1,407				84					210	23	3,895	863	6,863
AF9W			85								108					58	766	32	1,049
C7M																	10		10
C7P																		20	20
C9M											13						143	277	434
C9P																	100	279	379
C9W											139		137			68	220	378	941
D7M	152		8	176		141		622		295	26		86		802	180	180	23	2,690
D7P	195	22	119	430		140		226		564		15			42		326	273	2,352
D7W	46		26	59	32			174		91	14	16	89		543	204	54	14	1,363
D8M	120	125	783	278	1,474	725		28	9	2,783	108	32	7		2,139	96	155	193	9,058

Strata Acres	ANA	BIL	BOZ	CLW	CON	DIL	GLA	HAM	HAV	HEL	KAL	LEW	LIB	MIL	MSO	PLN	STW	SWN	Total
D8P	150	279	1,541	304	422	2,552	9		23	5,322	9	115	9		307	119	136	108	11,405
D8W	402		188	365	737	281		42	48	1,284	76	16	103		663	170	106	373	4,856
D9M	7,919	518	3,642	10,458	317	7,112	125	3,235	424	8,165	2,680	1,079	4,303		11,254	6,485	5,289	1,607	74,611
D9P	6,088	792	4,779	10,615	859	7,273	78	2,279	192	14,523	1,487	1,130	2,322		14,570	3,091	6,663	2,262	79,004
D9W	3,484	298	889	943		1,509		675	13	852	3,396	899	3,590		4,290	3,524	1,526	636	26,523
DL7M				237							867		240		831	221	562	301	3,258
DL7P				259							63		5				264	158	749
DL7W				526							535		461		1,671	511	747	83	4,534
DL8M				290							258		1,007		1,478	7	599	827	4,466
DL8P				97									9		69		130	253	558
DL8W				810							691		207		1,594	99	1,303	1,210	5,913
DL9M				6,603				163			11,119		2,698		3,311	5,601	6,241	4,039	39,775
DL9P				4,783				91			6,803		1,125		4,416	2,933	7,241	5,794	33,186
DL9W				771				94			7,627		2,162		2,044	2,465	2,042	578	17,783
GF7M											52						24	25	101
GF7P											22						36		58
GF7W															33	21	45		99
GF8M																	14	78	92
GF8P																		77	77
GF8W											14					24		89	128
GF9M											601				34	185	677	555	2,052
GF9P											187				14	44	32	1,120	1,397
GF9W											903				70	533	353	54	1,913
L7M				117							184		149		16	92	307	220	1,085
L7P				22									22		19	56	145	153	416
L7W				239							372		199		116	369	1,053	178	2,527
L8M				15							28		121		42		366	265	837
L8P																48	247	291	587
L8W				170							247		72		331	47	973	1,363	3,204
L9M				1,265				15			346		392		887	651	4,281	594	8,431
L9P				1,840				13			449		182		1,933	820	5,083	1,550	11,868
L9W				79							214		435		374	227	514	72	1,914
LP7M	220	40	36	127		175		948		104	151		402		162	206	697	148	3,414
LP7P	277		13	811		137		269	10	199	58	10			25	178	450	181	2,618
LP7W	585			480		203		1,482		269	227		100		1,031	638	6,357	637	12,010
LP8M	220		72	337		263		65		307	219	25	265		287	85	903	126	3,173
LP8P	281	9	61	231		214		7		47		42	19		40	67	547	67	1,632
LP8W	478	10	188	729		421		557		634	833	177	463		1,105	331	4,752	1,074	11,752
LP9M	353	392	681	670	38	697			52	1,048	105	593	42		294	27	1,257	339	6,588
LP9P	341	898	445	769	76	1,177			46	1,401	193	416	10		208	170	1,912	546	8,610

Strata Acres	ANA	BIL	BOZ	CLW	CON	DIL	GLA	HAM	HAV	HEL	KAL	LEW	LIB	MIL	MSO	PLN	STW	SWN	Total
LP9W			663	39		65				155	34	71			306	35	139	8	1,515
MC7M	11			614		9		17		12	64		138			32	688	243	1,828
MC7P				113								14	10		41		213	148	539
MC7W	40							57			51		139		155		1,099	313	1,853
MC8M				501		15					51				56	51	346	373	1,392
MC8P	128			53		32				166		20	8	11			29	289	735
MC8W	14			458				20			27		98		643	40	708	740	2,749
MC9M	114			3,126		550		50		134	365	6	191		1,490	277	1,806	988	9,097
MC9P	221	228	87	846		660		76		75	208	334	32		317	1,092	1,277	1,984	7,436
MC9W	22			110		102					478	133	389			408	694	126	2,462
NS6N	2,231	8,015	2,454	934		802		2,777	8	4,478	733	273	1,157	2,940	3,957	933	1,949	319	33,958
P7M	62	14		43				1,006		58	321	83	291	122	322	270	31	12	2,635
P7P	20	226		210				493		41		43	180	150	81	55	111		1,609
P7W	26			44				861		95	98	10	279		199	317			1,929
P8M	14	522		316			38		225	1,205	97	602	72	872	180	383		172	4,695
P8P	11	6,674		147			849	10	792	2,871		3,522	60	7,182		12			22,130
P8W				34			77			197	34	94	193	20	455	50			1,154
P9M	407	8,997		4,922			682	3,017	435	1,999	1,447	7,675	742	7,704	5,747	6,208	88	298	50,368
P9P	504	22,072	95	4,575			2,878	2,918	2,142	6,726	1,185	11,481	503	21,717	7,180	6,734	382	175	91,268
P9W		552		146				478			738	1,179	416		1,441	1,078		62	6,090
S7M																	309	36	344
S7P				28							7						75	133	243
S7W																	580		580
S8M											19						386	20	424
S8P				7							26						128	85	247
S8W											25						287	142	454
S9M	11			153		136					443		74			67	3,658	1,427	5,970
S9P	71			105		57					105		76			87	2,519	1,892	4,913
S9W	86			109		98					571		98		94	156	1,715	274	3,200
W1W1W1	1,032			1,712				284			524		931		285	34	559	17	5,378
W3W3W3	36			262				26			10		21		7	99	209	56	727
W4W4W4	37			1,046							1,331		1,833		967	441	7,234	8,715	21,604
W6W6W6				40											84	30	6,121	106	6,381
WH9M																31			31
WH9P											16								16
WH9W											109		33			19	14		175
WP7M																	12		12
WP7P																		655	655
WP7W											86					60			147
WP8M																		46	46

Strata Acres	ANA	BIL	BOZ	CLW	CON	DIL	GLA	HAM	HAV	HEL	KAL	LEW	LIB	MIL	MSO	PLN	STW	SWN	Total
WP9M																	65	39	104
WP9P											5						310	468	783
	26,514	**50,681**	**18,297**	**66,735**	**3,955**	**28,082**	**4,737**	**23,075**	**4,417**	**56,326**	**50,767**	**30,106**	**29,397**	**40,717**	**81,668**	**49,743**	**112,076**	**52,086**	**729,379**

Stocking Acres	ANA	BIL	BOZ	CLW	CON	DIL	GLA	HAM	HAV	HEL	KAL	LEW	LIB	MIL	MSO	PLN	STW	SWN	Total
None (NS)	2,231	8,015	2,454	934		802		2,777	8	4,478	733	273	1,157	2,940	3,957	933	1,949	319	33,958
Poor (P)	8,308	31,198	7,517	26,309	1,357	14,003	3,815	6,381	3,205	32,076	10,825	17,142	4,572	29,059	29,469	15,529	32,893	20,112	293,771
Mod. (M)	9,632	10,608	6,255	30,304	1,829	10,521	846	9,166	1,144	16,196	19,697	10,095	11,221	8,698	29,505	21,224	34,301	14,086	245,327
Well (W)	5,238	860	2,070	6,128	770	2,756	77	4,440	61	3,576	17,647	2,595	9,662	20	17,393	11,453	28,811	8,676	122,232
OG-W1	1,032			1,712				284			524		931		285	34	559	17	5,378
OG-W3	36			262				26			10		21		7	99	209	56	727
OG-W4	37			1,046							1,331		1,833		967	441	7,234	8,715	21,604
OG-W6				40											84	30	6,121	106	6,381
	26,514	**50,681**	**18,297**	**66,735**	**3,955**	**28,082**	**4,737**	**23,075**	**4,417**	**56,326**	**50,767**	**30,106**	**29,397**	**40,717**	**81,668**	**49,743**	**112,076**	**52,086**	**729,379**

Prod. Class Acres	ANA	BIL	BOZ	CLW	CON	DIL	GLA	HAM	HAV	HEL	KAL	LEW	LIB	MIL	MSO	PLN	STW	SWN	Total
Low (L)	7,285	50,681	13,071	5,498	3,955	25,066	4,737	4,640	4,417	44,254	1,201	30,106	901	40,717	7,496	5,234	12,311	1,100	262,671
Med. (M)	17,898			53,954				18,199			30,171		20,637		59,684	26,107	53,166	9,640	289,457
High (H)	1,331		5,226	7,283		3,015		235		12,072	19,395		7,859		14,488	18,402	46,598	41,346	177,251
	26,514	**50,681**	**18,297**	**66,735**	**3,955**	**28,082**	**4,737**	**23,075**	**4,417**	**56,326**	**50,767**	**30,106**	**29,397**	**40,717**	**81,668**	**49,743**	**112,076**	**52,086**	**729,379**

Deferred Acres	ANA	BIL	BOZ	CLW	CON	DIL	GLA	HAM	HAV	HEL	KAL	LEW	LIB	MIL	MSO	PLN	STW	SWN	Total
Out (N)	19,018	33,638	10,727	63,701	3,351	24,102		22,843	2,856	34,251	49,408	24,312	28,543	23,733	80,318	42,609	99,186	50,674	613,271
Lease Lots, Policy, Law	*6*	*885*	*318*	*1,354*		*93*				*453*	*415*	*207*	*669*	*132*	*87*	*192*	*262*	*424*	*5,499*
Low Productivity	*2,723*	*13,970*	*347*	*15*		*1,291*	*4,737*	*53*	*371*	*6,828*	*332*	*1,302*	*14*	*16,369*	*162*	*129*	*2,039*	*166*	*50,847*
Low Value - High Dev. Costs	*2,196*	*579*	*1,519*	*34*	*605*	*989*			*484*	*4,428*	*165*	*1,456*	*77*	*90*	*131*	*525*	*3,829*		*17,107*
No Legal Access	*1,249*		*3,728*	*162*		*1,292*			*530*	*8,657*	*401*	*1,713*		*351*	*607*	*5,347*	*1,889*	*67*	*25,994*
Timber Cons. License / Lease				*67*											*79*	*40*			*185*
Topography (steep, rocky, etc.)	*893*	*1,510*	*1,048*	*103*		*82*		*144*	*176*	*1,173*		*1,114*	*62*	*42*	*271*	*460*	*4,250*	*421*	*11,749*
Wet Areas	*428*	*99*	*610*	*1,300*		*232*		*34*		*536*	*47*		*32*		*13*	*440*	*621*	*332*	*4,725*
In (Y)	7,496	17,043	7,569	3,035	605	3,980	4,737	231	1,561	22,075	1,358	5,793	853	16,984	1,350	7,134	12,890	1,412	116,108
	34,010	**67,724**	**25,866**	**69,770**	**4,560**	**32,062**	**9,474**	**23,306**	**5,978**	**78,401**	**52,125**	**35,899**	**30,250**	**57,701**	**83,019**	**56,877**	**124,966**	**53,496**	**845,485**

Sens. Water. Acres	ANA	BIL	BOZ	CLW	CON	DIL	GLA	HAM	HAV	HEL	KAL	LEW	LIB	MIL	MSO	PLN	STW	SWN	Total
GOCR																		11,673	11,673
LACR																	8,266		8,266
LICR																		2,913	2,913
POWO																		19,169	19,169
SFLS																		17,602	17,602
STCC																	13,251		13,251
UPWH																	26,454		26,454
Out (N)	26,514	50,681	18,297	66,735	3,955	28,082	4,737	23,075	4,417	56,326	50,767	30,106	29,397	40,717	81,668	49,743	64,104	729	630,050
	26,514	**50,681**	**18,297**	**66,735**	**3,955**	**28,082**	**4,737**	**23,075**	**4,417**	**56,326**	**50,767**	**30,106**	**29,397**	**40,717**	**81,668**	**49,743**	**112,076**	**52,086**	**729,379**

UMZ Acres	ANA	BIL	BOZ	CLW	CON	DIL	GLA	HAM	HAV	HEL	KAL	LEW	LIB	MIL	MSO	PLN	STW	SWN	Total
Out (N)	26,514	50,681	18,297	66,735	3,955	28,082	4,737	23,075	4,417	56,326	50,767	30,106	29,397	40,717	81,668	49,743	110,128	51,956	727,302
In (Y)																	1,948	129	2,077
	26,514	**50,681**	**18,297**	**66,735**	**3,955**	**28,082**	**4,737**	**23,075**	**4,417**	**56,326**	**50,767**	**30,106**	**29,397**	**40,717**	**81,668**	**49,743**	**112,076**	**52,086**	**729,379**

Hel. Acres	ANA	BIL	BOZ	CLW	CON	DIL	GLA	HAM	HAV	HEL	KAL	LEW	LIB	MIL	MSO	PLN	STW	SWN	Total
Out (N)	25,972	50,681	18,037	66,165	3,955	28,082	4,737	22,918	4,417	56,326	50,103	30,106	28,748	40,717	81,668	49,589	103,166	51,531	716,917
In (Y)	542		260	571				157			664		649			154	8,910	555	12,461
	26,514	**50,681**	**18,297**	**66,735**	**3,955**	**28,082**	**4,737**	**23,075**	**4,417**	**56,326**	**50,767**	**30,106**	**29,397**	**40,717**	**81,668**	**49,743**	**112,076**	**52,086**	**729,379**

RMZ Acres	ANA	BIL	BOZ	CLW	CON	DIL	GLA	HAM	HAV	HEL	KAL	LEW	LIB	MIL	MSO	PLN	STW	SWN	Total
Out (N)	25,600	48,966	17,675	64,546	3,836	27,153	4,641	21,896	4,261	54,347	49,178	29,041	28,314	39,557	79,230	48,083	104,575	48,964	699,865
In (Y)	914	1,715	622	2,190	119	929	96	1,178	156	1,979	1,588	1,065	1,083	1,160	2,438	1,660	7,501	3,122	29,514
	26,514	**50,681**	**18,297**	**66,735**	**3,955**	**28,082**	**4,737**	**23,075**	**4,417**	**56,326**	**50,767**	**30,106**	**29,397**	**40,717**	**81,668**	**49,743**	**112,076**	**52,086**	**729,379**

GZB Vis. Acres	ANA	BIL	BOZ	CLW	CON	DIL	GLA	HAM	HAV	HEL	KAL	LEW	LIB	MIL	MSO	PLN	STW	SWN	Total
Out (N)	26,514	50,681	18,297	66,258	3,914	28,082	4,737	23,075	4,417	56,293	50,307	30,106	28,898	40,717	81,668	49,361	108,468	50,653	722,446
In (Y)				477	42					33	460		499			382	3,608	1,432	6,933
	26,514	**50,681**	**18,297**	**66,735**	**3,955**	**28,082**	**4,737**	**23,075**	**4,417**	**56,326**	**50,767**	**30,106**	**29,397**	**40,717**	**81,668**	**49,743**	**112,076**	**52,086**	**729,379**

GZB Class A Acres	ANA	BIL	BOZ	CLW	CON	DIL	GLA	HAM	HAV	HEL	KAL	LEW	LIB	MIL	MSO	PLN	STW	SWN	Total
1																	5,517		5,517
2																	7,184		7,184
3																	4,179		4,179
4																	1,370		1,370
Out (N)	26,514	50,681	18,297	66,735	3,955	28,082	4,737	23,075	4,417	56,326	50,767	30,106	29,397	40,717	81,668	49,743	93,826	52,086	711,129
	26,514	**50,681**	**18,297**	**66,735**	**3,955**	**28,082**	**4,737**	**23,075**	**4,417**	**56,326**	**50,767**	**30,106**	**29,397**	**40,717**	**81,668**	**49,743**	**112,076**	**52,086**	**729,379**

GZB Core Acres	ANA	BIL	BOZ	CLW	CON	DIL	GLA	HAM	HAV	HEL	KAL	LEW	LIB	MIL	MSO	PLN	STW	SWN	Total
Out (N)	26,514	50,681	18,297	66,735	3,955	28,082	4,737	23,075	4,417	56,326	50,767	30,106	29,397	40,717	81,668	49,743	77,713	52,086	695,015
In (Y)																	34,363		34,363
	26,514	**50,681**	**18,297**	**66,735**	**3,955**	**28,082**	**4,737**	**23,075**	**4,417**	**56,326**	**50,767**	**30,106**	**29,397**	**40,717**	**81,668**	**49,743**	**112,076**	**52,086**	**729,379**

GZB Sec. Zone Acres	ANA	BIL	BOZ	CLW	CON	DIL	GLA	HAM	HAV	HEL	KAL	LEW	LIB	MIL	MSO	PLN	STW	SWN	Total
Out (N)	26,514	50,681	18,297	66,735	3,955	28,082	4,737	23,075	4,417	56,326	50,767	30,106	29,397	40,717	81,668	49,743	90,110	52,086	707,413
In (Y)[26]																	21,966		21,966
	26,514	**50,681**	**18,297**	**66,735**	**3,955**	**28,082**	**4,737**	**23,075**	**4,417**	**56,326**	**50,767**	**30,106**	**29,397**	**40,717**	**81,668**	**49,743**	**112,076**	**52,086**	**729,379**

GZB Subunit Acres	ANA	BIL	BOZ	CLW	CON	DIL	GLA	HAM	HAV	HEL	KAL	LEW	LIB	MIL	MSO	PLN	STW	SWN	Total
GC																		12,195	12,195
LC																		3,337	3,337
PC																		631	631
PW																		18,303	18,303
SFLS																		17,331	17,331
SP																		289	289
Out (N)	26,514	50,681	18,297	66,735	3,955	28,082	4,737	23,075	4,417	56,326	50,767	30,106	29,397	40,717	81,668	49,743	112,076	1	677,294
	26,514	**50,681**	**18,297**	**66,735**	**3,955**	**28,082**	**4,737**	**23,075**	**4,417**	**56,326**	**50,767**	**30,106**	**29,397**	**40,717**	**81,668**	**49,743**	**112,076**	**52,086**	**729,379**

[26] The size of the Grizzly Bear Security Zones was estimated to be 21,966 acres of commercial forest at the time of modelling. Subsequently, a settlement has been reached with the plaintiffs, and the Grizzly Bear Security Zones will encompass 20,500 acres of commercial forest. It is our opinion that the difference between modeled and settlement acres will not cause a significant change in the sustained harvest level.

LMA Acres	ANA	BIL	BOZ	CLW	CON	DIL	GLA	HAM	HAV	HEL	KAL	LEW	LIB	MIL	MSO	PLN	STW	SWN	Total
CC																	14,685		14,685
GA				7,440											1,239				8,678
SE																	33,437		33,437
SLA				12,171															12,171
SW																	38,337		38,337
Swan																		51,797	51,797
Out (N)	26,514	50,681	18,297	47,124	3,955	28,082	4,737	23,075	4,417	56,326	50,767	30,106	29,397	40,717	80,430	49,743	25,617	289	570,273
	26,514	**50,681**	**18,297**	**66,735**	**3,955**	**28,082**	**4,737**	**23,075**	**4,417**	**56,326**	**50,767**	**30,106**	**29,397**	**40,717**	**81,668**	**49,743**	**112,076**	**52,086**	**729,379**

Pot. Lynx Hab. Acres	ANA	BIL	BOZ	CLW	CON	DIL	GLA	HAM	HAV	HEL	KAL	LEW	LIB	MIL	MSO	PLN	STW	SWN	Total
Out (N)	20,602	46,474	2,556	46,882	3,018	4,375	4,737	21,566	4,417	40,229	27,139	27,837	19,650	40,717	62,302	27,503	10,680	2,989	413,673
In (Y)	5,912	4,207	15,741	19,853	937	23,707		1,509		16,097	23,628	2,269	9,747		19,366	22,240	101,396	49,097	315,706
	26,514	**50,681**	**18,297**	**66,735**	**3,955**	**28,082**	**4,737**	**23,075**	**4,417**	**56,326**	**50,767**	**30,106**	**29,397**	**40,717**	**81,668**	**49,743**	**112,076**	**52,086**	**729,379**

Bald Eagle Acres	ANA	BIL	BOZ	CLW	CON	DIL	GLA	HAM	HAV	HEL	KAL	LEW	LIB	MIL	MSO	PLN	STW	SWN	Total
Out (N)	26,481	50,522	18,297	65,938	3,955	28,015	4,737	22,871	4,417	56,191	50,386	30,106	28,811	40,717	80,217	49,388	109,694	51,871	722,614
In (Y)	33	159		797		67		203		135	380		586		1,452	355	2,383	215	6,765
	26,514	**50,681**	**18,297**	**66,735**	**3,955**	**28,082**	**4,737**	**23,075**	**4,417**	**56,326**	**50,767**	**30,106**	**29,397**	**40,717**	**81,668**	**49,743**	**112,076**	**52,086**	**729,379**

Current OG Acres	ANA	BIL	BOZ	CLW	CON	DIL	GLA	HAM	HAV	HEL	KAL	LEW	LIB	MIL	MSO	PLN	STW	SWN	Total
Out (N)	25,018	50,681	18,297	63,676	3,955	26,466	4,737	22,765	4,361	56,093	48,901	29,899	26,612	40,717	80,325	49,139	97,937	43,192	692,770
In (Y)	1,495			3,060		1,616		310	56	233	1,865	206	2,785		1,344	604	14,139	8,893	36,609
	26,514	**50,681**	**18,297**	**66,735**	**3,955**	**28,082**	**4,737**	**23,075**	**4,417**	**56,326**	**50,767**	**30,106**	**29,397**	**40,717**	**81,668**	**49,743**	**112,076**	**52,086**	**729,379**

11 Appendix D: Management Pathways

The following tables show the combinations of land office, species and productivity class that were eligible for each management pathway (Rx). These tables also show the types of silvicultural treatments that each pathway was eligible for. These treatments can be classified as either pre-commercial thinning (PCT), commercial thinning (CT), or selection harvest (Sel.). PCT treatments were defined in terms of age of treatment and after-harvest trees per acre (TPA). CT treatments were defined in terms of earliest age of treatment and after-harvest basal area (BA). The selection harvest for the uneven-aged pathways (UERX) were defined in terms of earliest age of treatment, residual BA target and re-entry period, while the old-growth selection harvests (OGRX) were defined in terms of after-harvest BA, TPA larger than a threshold diameter at breast height (DBH), and re-entry period. The even-aged pathways (EARX) were also defined in terms of the number of leave trees associated with each harvest intensity type (CC, ST, or SW).

Each of the management pathways were labelled with a unique 7 digit Rx code, with each digit describing a different aspect of the pathway. This allowed each pathway to be labeled with a unique code that could be used as a reference for the silvicultural treatments within the pathway. The following table describes the composition of the Rx codes in further detail:

Table 24: Key to the Rx Codes

Digits	Group	Code	Definition
1	Strata Type	E	Existing Strata
		N	Future (Regeneration) Strata
2	PCT	+	No PCT
		2	PCT at Age 20
		3	PCT at Age 30
3 to 4	CT and Sel. Harvest	++	No CT or Selection Harvest
		1B	One CT to a BA Target
		MB	Multiple Selection Harvests to a BA Target
5	Fertilization	+	No Fertilization
6 to 7	Rx Type	CC	EARX with Clear-Cut Regeneration Harvest
		ST	EARX with Seed-Tree Regeneration Harvest
		SW	EARX with Shelter-Wood Regeneration Harvest
		UD	UERX on Dry Site
		UM	UERX on Moist Site
		UW	UERX on Wet Site
		W1	OGRX on W1
		W3	OGRX on W3
		W4	OGRX on W4
		W6	OGRX on W6

Table 25: Even-Aged Management Prescriptions for Existing Strata (EARX)

Rx	Land Office	Forest Type (Species)	Productivity Class	PCT Age	PCT TPA	CT Age	CT BA	Residual TPA
E++++CC	All	AF, LP, S + W3, W6	ALL	None	None	None	None	4
E2+++CC	NW, SW	AF, LP, S	H, M	20	300	None	None	4
E2+++CC	CE	AF, LP, S	H	20	300	None	None	4
E++++ST	All	All (No LP, P) + W1, W4, W6	All	None	None	None	None	8
E2+++ST	All	All (No LP, P)	H	20	300	None	None	8
E3+++ST	All	All (No LP, P)	M	30	250	None	None	8
E21B+ST	All	All (No LP, P)	H	20	435	60	80	8
E++++SW	All	All (No LP) + W1, W4, W6	All	None	None	None	None	30
E2+++SW	All	All (No LP)	H	20	300	None	None	30
E3+++SW	All	All (No LP)	M	30	250	None	None	30
E21B+SW	All	All (No LP)	H	20	435	60	80	30

Table 26: Uneven Aged Management Prescriptions (UERX)

Rx	Land Office	Forest Type (Species)	Productivity Class	PCT Age	PCT TPA	Sel. First Harv. Age	Sel. Res. BA	Sel. Re-Entry
E+MB+UD	All	D, P	All	None	None	70	±45	40
E2MB+UD	All	D, P	H, M	20	250	60	±45	40
E+MB+UM	NW, SW	AF, DL, GF, L, WP	All	None	None	80	±80	30
E2MB+UM	NW, SW	AF, DL, GF, L, WP	H, M	20	250	70	±80	30
E+MB+UW	NW, SW	C, MC, S, WH	All	None	None	90	±120	30
E2MB+UW	NW, SW	C, MC, S, WH	H, M	20	250	80	±120	30

Table 27: Old-Growth Management Prescriptions (OGRX)

Rx	Land Office	Forest Type (Species)	Productivity Class	Sel. Res. BA	Sel. TPA Large Trees	Sel. Large Tree DBH	Sel. Re-Entry
E+MB+W1	NW, SW	W1	All	60	10	21	30
E+MB+W3	NW, SW	W3	All	70	12	13	30
E+MB+W4	NW, SW	W4	All	100	12	21	50
E+MB+W6	NW, SW	W6	All	80	12	13	50

Table 28: Even-Aged Management Prescriptions for Future Strata (EARX)

Rx	Land Office	Forest Type (Species)	Productivity Class	PCT Age	PCT TPA	CT Age	CT BA	Residual TPA
N++++CC	All	AF, LP, S + W3, W6	ALL	None	None	None	None	4
N2+++CC	NW, SW	AF, LP, S	H, M	20	300	None	None	4
N2+++CC	CE	AF, LP, S	H	20	300	None	None	4
N++++ST	All	All (No LP, P) + W1, W4, W6	All	None	None	None	None	8
N2+++ST	All	All (No LP, P)	H	20	300	None	None	8
N3+++ST	All	All (No LP, P)	M	30	250	None	None	8
N21B+ST	All	All (No LP, P)	H	20	435	60	80	8
N++++SW	All	All (No LP) + W1, W4, W6	All	None	None	None	None	30
N2+++SW	All	All (No LP)	H	20	300	None	None	30
N3+++SW	All	All (No LP)	M	30	250	None	None	30
N21B+SW	All	All (No LP)	H	20	435	60	80	30

12 Appendix E: Selection Harvest Reversed J-Curves

The reversed J-Curves for UERX were developed through a series of trials. Initially only three curves were defined, one each for dry, moist and wet sites. Each of these curves had a Q-factor, a DBH range from zero to 24, a DBH class size of 4”, and retained 2 TPA larger than 24”. All of them also used a 30 year re-entry period. Implementation of these curves showed unacceptably large BA reductions following selection harvests, often resulting in tree lists that were well below their BA target and unsustainable with regards to volume. The solution was to follow a tiered approach, which incrementally decreased the BA target until the desired level was reached (Don’t try to get to future desired condition in one step). This approach worked well for moist and wet sites, resulting in two tiers each. For moist sites the first tier targeted 115 BA with a Q-factor of 1.8, while the second tier targeted 80 BA with a Q-factor of 1.4. For wet sites the first tier targeted 115 BA with a Q-factor of 2.0, while the second tier targeted remained at 115 BA, but with a Q-factor of 1.7. For dry sites more trials were needed. A three tier approach with a 40 year re-entry period was investigated, which worked well for NW and SW strata. For these strata the first tier targeted 85 BA with a Q-factor of 1.7, the second tier targeted 65 BA with a Q-factor of 1.5, and the third tier targeted 45 BA with a Q-factor of 1.2. The CE and EA strata however still showed residual BA falling well below the target. Following more trials a two tier approach was adopted for these strata using a DBH range between zero and 20”, and 1 TPA larger than 20”. For these strata the first tier targeted 80 BA with a Q-factor of 2.8, while the second tier targeted 50 BA with a Q-factor of 2.2.

Table 29: Reversed J-Curve Definitions

Rx	Land Office	Tier	BA Target	Q-Factor	DBH From	DBH To	TPA
UD	CE, EA	1	80	2.8	0	4	335
UD	CE, EA	1	80	2.8	4	8	120
UD	CE, EA	1	80	2.8	8	12	43
UD	CE, EA	1	80	2.8	12	16	15
UD	CE, EA	1	80	2.8	16	20	5
UD	CE, EA	1	80	2.8	20	99	1
UD	CE, EA	2	50	2.2	0	4	125
UD	CE, EA	2	50	2.2	4	8	57
UD	CE, EA	2	50	2.2	8	12	26
UD	CE, EA	2	50	2.2	12	16	12
UD	CE, EA	2	50	2.2	16	20	5
UD	CE, EA	2	50	2.2	20	99	1

Rx	Land Office	Tier	BA Target	Q-Factor	DBH From	DBH To	TPA
UD	NW, SW	1	85	1.7	0	4	90
UD	NW, SW	1	85	1.7	4	8	53
UD	NW, SW	1	85	1.7	8	12	31
UD	NW, SW	1	85	1.7	12	16	18
UD	NW, SW	1	85	1.7	16	20	11
UD	NW, SW	1	85	1.7	20	24	6
UD	NW, SW	1	85	1.7	24	99	2
UD	NW, SW	2	65	1.5	0	4	46
UD	NW, SW	2	65	1.5	4	8	31
UD	NW, SW	2	65	1.5	8	12	21
UD	NW, SW	2	65	1.5	12	16	14
UD	NW, SW	2	65	1.5	16	20	9
UD	NW, SW	2	65	1.5	20	24	6
UD	NW, SW	2	65	1.5	24	99	2
UD	NW, SW	3	45	1.2	0	4	15
UD	NW, SW	3	45	1.2	4	8	12
UD	NW, SW	3	45	1.2	8	12	10
UD	NW, SW	3	45	1.2	12	16	8
UD	NW, SW	3	45	1.2	16	20	7
UD	NW, SW	3	45	1.2	20	24	6
UD	NW, SW	3	45	1.2	24	99	2
UM	All	1	115	1.8	0	4	146
UM	All	1	115	1.8	4	8	81
UM	All	1	115	1.8	8	12	45
UM	All	1	115	1.8	12	16	25
UM	All	1	115	1.8	16	20	14
UM	All	1	115	1.8	20	24	8
UM	All	1	115	1.8	24	99	2
UM	All	2	80	1.4	0	4	45
UM	All	2	80	1.4	4	8	32
UM	All	2	80	1.4	8	12	23
UM	All	2	80	1.4	12	16	16
UM	All	2	80	1.4	16	20	12
UM	All	2	80	1.4	20	24	8
UM	All	2	80	1.4	24	99	2

Rx	Land Office	Tier	BA Target	Q-Factor	DBH From	DBH To	TPA
UW	All	1	115	2.0	0	4	197
UW	All	1	115	2.0	4	8	99
UW	All	1	115	2.0	8	12	49
UW	All	1	115	2.0	12	16	25
UW	All	1	115	2.0	16	20	12
UW	All	1	115	2.0	20	24	6
UW	All	1	115	2.0	24	99	2
UW	All	2	115	1.7	0	4	122
UW	All	2	115	1.7	4	8	72
UW	All	2	115	1.7	8	12	42
UW	All	2	115	1.7	12	16	25
UW	All	2	115	1.7	16	20	15
UW	All	2	115	1.7	20	24	9
UW	All	2	115	1.7	24	99	2

13 Appendix F: Interaction between the Forest Plan Constraints and the Non-Declining Yield Constraint

When the Forest Plan constraints are imposed on a model with a non-declining yield constraint, the model assigns a number of acres to the no-harvest regimes. The explanation behind this phenomenon is somewhat technical and can best be understood through a simple example.

Suppose there is a 100 acre forest of one type that has 100 units of timber per acre. We are interested in calculating a sustainable yield over two periods, P1 and P2.

We can allocate acres between two management regimes:

- Regime E is an even-aged regime. The future stand will be more productive than the existing stand, as it will have more desirable stocking, brush control, etc. Clearcutting the stand in P1 yields 100 units per acre. The stand can then be clear-cut again in P2 yielding 110 units per acre.
- Regime U is an uneven-aged regime. The first entry in P1 reduces stocking to desired levels, yielding 50 units per acre. The second entry in P2 harvests the growth on the residual stand, and yields only 40 units per acre.

The variables in the problem are:

E = number of acres assigned to the even-aged regime

U = number of acres assigned to the uneven-aged regime

We can represent this problem with two equations:

1. All of acres must be allocated between these two regimes:
   $U + E = 100$
2. The harvest in Period 1 must be equal to the harvest in Period 2
   $H1 = H2$

   Where:

   $H1 = 100E + 50U$

   $H2 = 110E + 40U$

   Therefore:

$$100E + 50U = 110E + 40U$$

The solution here is E=50 and U = 50. In short, the decline in harvest from the U regime is offset by the increase in harvest from the E regime on an acre by acre basis.

Now suppose that we have a new constraint limiting the number of acres that can be assigned to the E regime to 40. We have to add a new variable:

Z = acres assigned to the “no-harvest” regime.

Our problem then becomes:

$$E + U + Z = 100$$

$$E <= 40$$

$$100\,E + 50\,U + 0Z = 110\,E + 40\,U + 0Z$$

The solution is E = 40, U = 40 and Z = 20. In short, the new limit on the number of acres that can be assigned to E results in 20 acres going to the no-harvest prescription.

Under a non-declining yield constraint, each acre of the U regime requires one acre of E regime to offset the declining volume from the U regime. A limit on the acres that can be assigned to the E regimes translates into a limit on the acres that can be assigned to the U regimes as well. As a result, some acres must take the no-harvest Z regime.

This is a highly simplified version of what is happening in the Forest Management Model. In general, however, the even-aged regimes produce somewhat higher volumes in future rotations. The uneven-aged regimes produce somewhat lower volumes in future entries. As a result, limiting the number of acres that can be assigned to even-aged regimes, forces some acres to the no-harvest regime, given the non-declining yield constraint.

77-5-221. Definition. As used in 77-5-222, 77-5-223, and this section, "annual sustainable yield" means the quantity of timber that can be harvested from forested state lands each year in accordance with all applicable state and federal laws, including but not limited to the laws pertaining to wildlife, recreation, and maintenance of watersheds, and in compliance with water quality standards that protect fisheries and aquatic life and that are adopted under the provisions of Title 75, chapter 5, taking into account the ability of state forests to generate replacement tree growth.

History: En. Sec. 1, Ch. 517, L. 1995.

77-5-222. Determination of annual sustainable yield. (1) (a) On July 1, 2013, the department, under the direction of the board, shall commission a new study by a qualified independent third party to determine, using scientific principles, the annual sustainable yield on forested state lands. The department shall direct the qualified independent third party to determine the yield pursuant to, but not exceeding, all state and federal laws.

(b) A new study may be commissioned by the department, under the direction of the board, at any time during the 10-year period provided for in subsection (2).
(2) A determination of annual sustainable yield under subsection (1) must be reviewed and re-determined by the department, under the direction of the board, at least once every 10 years.

History: En. Sec. 2, Ch. 517, L. 1995; amd. Sec. 1, Ch. 440, L. 2003; amd. Sec. 1, Ch. 288, L. 2013.

77-5-223. Annual sustainable yield as timber sale requirement -- review. The annual sustainable yield constitutes the annual timber sale requirement for the state timber sale program administered by the department. This annual requirement may be reduced proportionately by the amount of sustained income to the beneficiaries generated by site-specific alternate land uses approved by the board based on a determination under 77-5-222.

History: En. Sec. 3, Ch. 517, L. 1995 ; amd. Sec. 2, Ch. 288, L. 2013.

15 Appendix H: List of Contributors

Mason Bruce, and Girard, Inc.

Mark Rasmussen

Henk Stander

Brandon Vickery

Jessica Burton Desrocher

BDL Forestry, LLC

Brian Long

DNRC Contributors

Sonya Germann, Forest Management Bureau Chief

Gary Frank, Deputy Forest Management Bureau Chief, DNRC Project Leader

Tim Spoelma, Forest Management Bureau Silviculturist/Forest Ecologist

Mark Slaten, Forest Management Bureau Lead Inventory Forester

Dan Rogers, Forest Management Bureau Inventory Section Supervisor

Wayne Lyngholm, Forest Management Bureau Inventory Forester

Ross Baty, Forest Management Bureau Wildlife Biologist

Jordan Larson, Forest Management Bureau Economist

Jessica Brown, Forest Management Bureau Intern

Mike McMahon, Stillwater Unit Forest Management Supervisor

Jason Parke, Swan Unit Forest Management Supervisor

Pete Seigmund, Kalispell Unit Forest Management Supervisor

Dave Marsh, Libby Unit Forest Management Supervisor

Jon Hayes, Southwestern Land Office Silviculturist

Chuck Barone, Bozeman Unit Forester

Chris Pileski, Eastern Land Office Area Manager

Andy Miller, Eastern Land Office Forester

Shawn Thomas, Trust Land Management Division Administrator

Donna Riebe, GIS—Information System Support

- March 23, 2015 – New DNRC website launched with webpages on SYC information, process, announcements, and public participation. Included instructions on how to request a public meeting, contact, and join the SYC email list.
- April 14, 2015 – Briefed field staff on preliminary SYC Draft Report and answered questions.
- May 5, 2015—Presented Draft SYC Report results to DNRC Leadership and answered questions.
- May 6, 2015 – Announced the upcoming SYC Draft Report via email to public and DNRC website. Included an overview, how to request a public meeting and copy of the report, links to the website, and an update on the process.
- May 7, 2015—Presented Draft SYC Report results to field staff and answered questions.
- May 12, 2015—Updated Land Board Staffers on Draft SYC Report results and answered questions.
- May 17, 2015 – Completion of the SYC Draft Report.
- May 18, 2015 – Emailed SYC Draft Report for public review. Included how to request a public meeting, submit comments, receive a hard copy, and contact information. Posted online was a copy of the report, FAQ, and an executive summary.
- May 18, 2015 to June 17, 2015 – Official 30 day public review period of SYC Draft.
- June 4, 2015 – DNRC Timber Sale Purchasers' Meeting. Attendees heard a presentation on the SYC, asked questions, and received copies of the Draft Report, FAQ, executive summary, and sheets for public comments.
- June 6, 2015 – Announced the extended SYC Draft Report public review period via email and website. The new review period was May 18- July 2.
- June 12, 2015 – Held another meeting for members of the Montana Wood Products Association about the SYC.
- July 2, 2015 – End of public review period.
- August 24, 2015 – DNRC completed written responses to public comments.
- September 21, 2015 – SYC Final Report presented to the Land Board.

17 Appendix J: Responses to Public Comments

Following are ten comments that were received by the DNRC regarding the Draft Sustainable Yield Calculation Report. Individual public comments represented by a "C" while an "R" represents the MBG/DNRC response:

C1. I am quite frankly disappointed that with a 67,000 +/- acre increase in managed forest land base the SYC shows only a 0.3% increase in sustained yield. I do not believe that the SYC report adequately explains why there is a projected 25% decrease in per acre yield across the entire forest land base compared to previous models.

R1. Although DNRC acquired approximately 67,000 acres of former industry owned timberland, only 59,211 acres of the acquired lands were commercial forest that were included in the SYC model solution. The remaining acres were non-forested, non-commercial forest, deferred, Riparian Management Zones, or areas requiring Helicopter harvest that were removed from the model solution.

The maximum biological potential resulting from this sustainable yield calculation (SYC) is 80.3 MMBF, with 722,833 acres of commercial forest land contributing to that yield (see page 57 of this report). On a per acre basis, this equates to 111 board feet per acre per year statewide, which compares favorably with several published growth rates from past forest survey efforts in Montana (see Appendix R). The per acre biological potential in the 2004 and 2011 SYC was approximately 141 board feet per acre per year statewide. Comparatively, the biological potential in the 2015 SYC is about 22 percent less than in 2004 and 2011. When the model is fully constrained, the per acre yield is 99 board feet per acre per year (57.8 MMBF/582,944 acres, page 65), compared to 123 board feet per acre per year in 2004 and 2011 (57.6 MMBF/469,159 acres, page 24), representing a 20 percent decrease from 2004/2011 to 2015. These differences as stated in the draft report are attributable to several factors that affect both the current condition of the forested land bases as well as the projected yields associated with harvesting, including 1) source data, 2) impacts of mortality in existing stands, 3) updated classification of deferred acres, and 4) growth model and calibration.

1. Improved data (described on page 26), specifically the availability of plot data collected from State Trust Lands resulted in a more accurate depiction of standing inventory and forest conditions compared to prior SYC efforts that relied on data collected from other sources than State Trust Lands.

2. Mortality caused by wildfire and insects since 2004 has reduced the current standing volume on trust lands on a per acre basis. As mentioned on page 26, mortality that occurred between 2004 and 2011 was not included in the 2011 calculation, since both calculations used the same forest inventory data. The average per acre volume in 2004 and 2011 was 5.77 MBF/ac. compared to 5.39 MBF/ac. in 2015 (7 percent decrease per acre). This decrease is data-driven (rather than growth and yield model-driven), as current mortality was captured by the plot data collected in 2015. Decreased standing volume per acre results in a reduction in the potential harvest volume from existing stands, and therefore a corresponding decrease in the calculated annual sustainable yield.

3. Updated identification of deferred areas increased the amount of deferred acres when compared to previous sustainable yield calculations. This update resulted in an increase in the amount of deferred acres from approximately 89,000 acres in 2011 to approximately 116,000 acres in 2015. Deferred stands were identified by each field unit as those areas that could not be accessed or were not feasible to include in the SYC model solution. Most of the deferrals are due to low productivity forest types, areas with no legal access, or low valued timber with high road development cost. Other reasons for deferral included leased lots, steep topography and wet areas not associated with SMZs. Appendix C shows the deferred acres by unit and reason for deferral. These acres are removed from management in the model solution.

4. The Forest Vegetation Simulator (FVS) was used as the growth and yield model for this effort and it was calibrated using DNRC data, whereas prior efforts used different models and different calibration. Pages 35 - 43 describe in detail the process used to develop growth and yield tables, including model inputs (pages 36 - 39), calibration (pages 39 - 40), management regimes (pages 40 - 42) and regeneration (pages 42 - 43). Regarding calibration, DNRC's plot data collected in 2014 was relied on to verify projected yields (page 40), while the 2004 and 2011 calculations relied on data from Idaho forests that have higher productivity and potential growth than Montana forests that may have resulted in optimistic forecasts of growth and yield for those efforts.

C2. An ongoing investment in forest inventory must be made, not only to gain information on available timber volumes, but also as a monitoring and verification tool. Specifically, we suggest the DNRC collect data on growth and productivity of various forest sites under multiple management schemes. Focusing your data collection efforts on the most productive Trust Lands will generate the best returns on investment. The agency should look for opportunities to cooperate with other agencies and forest landowners, specifically with respect to gathering and sharing growth and yield data across the landscape.

R2. DNRC concurs with the importance of ongoing investments in collecting forest inventory data. On page 69, MB&G recommends continued investments to build on and strengthen the data used for this SYC effort, and to re-verify growth and yield model calibration and projections on a periodic basis as new data and models become available. DNRC intends to continue with and expand data collection efforts to improve estimates of the full range of forest conditions observed on State Trust Lands, as well as explore opportunities to improve growth and yield projections, including potential cooperative partnerships.

C3. It could be debated whether the proposed harvest level does the trust land mandate justice with respect to generating a reasonable return on its asset.

R3. In completing the SYC, DNRC relied on a third party contractor (MB&G) to conduct an objective and scientifically credible calculation. In developing the SYC, MB&G utilized the best baseline stand data and growth and yield information available. MB&G and DNRC believe that the management regimes and constraints utilized in the SYC accurately depict the harvest prescriptions, mitigation measures, regulations and practices consistent with the State Forest Land Management Plan (SFLMP), Administrative Rules applicable to DNRC forest management, Habitat Conservation Plan (HCP) and other laws and policies directing the DNRC Forest Management Program. The goal of this project was to determine from a statewide level, the amount of timber that could be sustainably harvested from State trust lands over the long-term. DNRC considers this sustainability one of the most important criteria for a return on assets from forested state trust lands. Over the past eight fiscal years (2007-2014), revenues from the Forest Management Program averaged over $9.6 million per year with a revenue to cost ratio of 1.67:1. For the last year for which data is available, Forest Management Program revenues were over $11.2 million with revenue: cost ratio greater than 2:1. Appendix A of this report shows that estimated annual revenues for each scenario evaluated would be greater than $12 million, indicating that DNRC's Forest Management Program will continue to generate a sustainable and positive return on the trusts' forested assets over a long term.

C4. Review of the assumptions made in this model in context with newly collected data and monitoring will likely suggest a need for recalculation of the SY on a timeframe shorter than the normal 10 years.

R4. The sustainable yield law requires DNRC to conduct a new study at least once every 10 years or as directed by the Land Board. For this calculation DNRC relied on a third-party contractor to conduct an objective and scientifically defensible calculation that is well supported. MB&G used the best data available and incorporated logical assumptions and constraints based on existing policy and legal framework. MB&G and DNRC believe that the calculation and outputs are sound, sustainable, and reflect the appropriate harvest level for state trust lands at this time. In addition, DNRC intends to expand data collection efforts to improve estimates of the full range of forest conditions observed on State Trust Lands, as well as explore opportunities to improve growth and yield projections, including potential cooperative partnerships. Should appreciable changes occur to our existing policy framework, or monitoring data suggest substantive change in yield projections or baseline forest condition prior to the 10-year SYC timeframe, a new calculation could be warranted as directed by the Land Board.

C5. The SYC states that big game habitat considerations were addressed through “coarse filter management and general application of allowable harvest prescriptions by cover type”. While it isn’t entirely clear in the SYC how big game winter range is accounted for in yield calculations or how the SYC will guide timber harvest on winter range, FWP encourages DNRC to Consider timber harvest activities that provide adequate canopy cover for snow intercept and thermal cover for wintering big game species. Harvest considerations should include both short-term and long-term effects on big game winter range throughout the entire extent of the winter range, accounting for past and future impacts. These considerations should be reflected in the yield calculations utilized in the SYC Draft Report and be reflected in on-the-ground management actions.

R5. The sustainable yield calculation incorporates programmatic management constraints that have clear, predictable influence on realized timber volume that may be harvested from state trust lands each year (e.g. deferred grizzly bear security core areas). Most of these specific constraints are codified in DNRC’s Forest Management Administrative Rules (ARMs). As a part of DNRC’s programmatic development and adoption of the State Forest Land Management Plan (SFLMP), no specific winter range cover requirements were established that would influence sustainable yield calculations required by statute each decade. However big game habitat was still identified as an important consideration in the SFLMP and ARMs (ARM 36.11.443). Short and long-term effects to these habitat attributes as mentioned in this comment were considered in the programmatic SFLMP EIS, and are addressed project by project during project level MEPA analyses. Such analysis is beyond the scope and intent of the sustainable yield calculation report. That said, assurances that cover across the landscape is provided in various ways by many overlapping constraints, such as the pool of deferred acres, grizzly bear cover, old growth, riparian management constraints, and allowable harvest prescriptions by cover type etc. DNRC will continue to involve DFWP in the development of forest management projects proposed statewide and address big game concerns to the extent possible via making choices about treatment types on a stand by stand basis.

C6. Not covered in the SYC is the understory treatment associated with timber harvest and how it influences plant compositions. FWP encourages DNRC to consider harvest strategies and treatment plans that maintain diverse plant communities, yet limit establish of invasive species. Disturbance associated with timber harvest has the potential to increase noxious weeds growth and spread, which ultimately influences the overall productivity of the site, both for regenerating plant communities and for wildlife.

R6. Understory treatment of trees actually was a consideration in the calculation and report (4.2.6.8 Management Regimes, pp. 38-40). For each treatment type established, pathways were developed that included options for pre-commercial thinning. Choices and management considerations beyond those that would influence young and old trees were beyond the scope and intent of the calculation and report. For the calculation, 17 distinct management prescriptions were identified and included in the model, that when implemented, would provide a diverse range of habitat conditions and cover amounts across the landscape. These prescriptions as applied in the model are consistent with the intent and required constraints contained in the State Forest Land Management Plan (SFLMP) and Forest Management Rules (ARMs). The SFLMP and ARMs respectively include comprehensive analysis and measures to address invasive plant species that are implemented at the project level (ARM 36.11.445). Potential for local impacts and mitigations to minimize spread and establishment of invasive species are addressed in each MEPA analysis for specific forest management projects, and required measures to minimize spread and establishment of invasive species are included in timber sale contracts.

C7. The model contains assumptions on average mortality by stand types across State forest lands. However, it is logical that any salvage sales/permits or limited access permits should be considered "in addition" to the sustainable yield harvest level. This approach not only adds return to the Trust Beneficiaries but, is easily offset through the 20 MMBF/Year in biological volume accumulated every year through deferrals and management constraints.

R7. Most DNRC timber sales include some degree of salvage harvest due to individual tree mortality or poor forest stand conditions. It would be difficult to calculate the amount of salvage volume versus green volume contained in timber sales prepared to meet SYC targets. When large catastrophic tree mortality occurs on forested trust lands DNRC typically exceeds it SYC targets by carrying out focused savage efforts. In the future it is likely that DNRC would continue to carry out salvage efforts that exceed SYC targets in order to capture time sensitive timber values. However, there is a limit to the amount of total volume DNRC can accomplish due to finite staff and resources. Areas with known or expected limited access opportunities were not deferred from the SYC model solution.

C8. Trust Lands Division should not count dead volume sold as part of the calculation. This volume should not matter as it makes no difference to the sustained yield. We are concerned that this reduction set a precedent for future large mortality events as future calculations will be reduced and volume will not be captured and delivered to the market. The Division already includes a mortality factor in the calculation.

R8. Volume in DNRC's inventory that is currently dead as result of past events (insects, disease, wildfires, etc.) is not projected forward by the model and is not included in the reported sustainable yield; only live volume is reported and carried forward by the model during the calculation. The growth and yield model does account for mortality due to inter-tree competition through the planning horizon, but it does not include any prediction of future events that could induce widespread mortality such as fire or extensive insect outbreaks. As such, the volume in trees that could be affected by future events causing widespread mortality would be considered as live volume by the model and would thus be included in both the calculated annual sustainable yield and potential future harvests implemented by DNRC whether dead or alive at the time of harvest. Depending on the timing of such potential events, there could be an impact on the amount of standing volume estimated at the outset of future calculations, and that is one reason for conducting periodic updates of the annual sustainable yield.

C9. Modeling forest landscapes over long periods of time, with multiple constraints, is very difficult. Therefore, it is essential that the best available data is used, including characterization of existing conditions and projection of future growth, mortality and management.

R9. We agree that the processes used to complete the SYC are complex and require a thoughtful approach, and that the results are highly dependent upon the quality of the data supplied. With that in mind, DNRC made a concerted effort to follow recommendations from prior sustainable yield calculations and provide the third-party contractor, MB&G, with the best data available to us for this calculation (as described on pages 25 - 27 of this report). DNRC also incorporated logical assumptions and constraints based on our existing program, policies and legal framework. We relied appropriately on MB&G to conduct an objective and scientifically defensible calculation, and believe that both the calculation and outputs are sound, sustainable, and reflect the appropriate harvest level for state trust lands at this time.

C10. Now that the Division owns the modeling software and has added plots, it is vital that the Division continually reconciles the assumptions made in the model with actual ground-truth data at acceptable intervals instead of waiting ten years until the next recalculation is due.

R10. The software used for the growth and yield portion of the SYC was the Forest Vegetation Simulator (FVS) model. This software is freely available and was developed, and is distributed for use by the U.S. Forest Service. However, the spatial planning system used for the optimization and harvest scheduling portion of the SYC is licensed software from Remsoft. DNRC does not currently own this Remsoft software. MB&G has recommended that DNRC revisit and verify model calibration on an ongoing basis as new data and models become available, as well as engage with the U.S. Forest Service to improve the performance of FVS for DNRC land (see page 69 of this report). DNRC intends to follow that recommendation in order to build on this effort and increase its understanding of forest growth on its managed lands, as well as gain efficiency in growth and yield modeling for future efforts.

18 Appendix K: DNRC Forest Inventory Report

Montana Department of Natural Resources and Conservation manages approximately 730,000 acres of commercial forestland on state trust lands throughout Montana[27]. Those acres are divided into four Land Offices for management purposes: Northwestern (NW), Southwestern (SW), Central (CE), and Eastern (EA). Figure 11 shows the distribution of these acres across the state by Land Office.

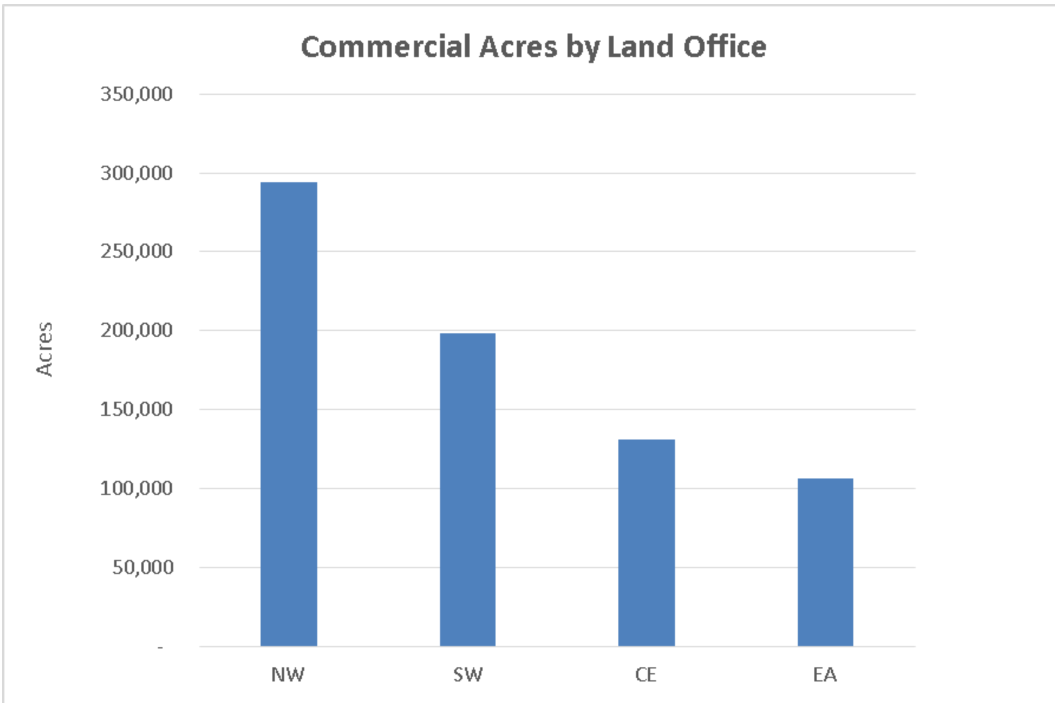


Figure 11: Commercial Acres of DNRC Forest Land by Land Office

There are about 294,000 acres in the Northwestern Land Office (40%), the largest land base in the state, followed by the Southwestern Land Office at about 198,000 acres (27%). The Central and Eastern Land Offices total 237,000 acres combined (33%).

Within these four Land Offices, the forested land base is further divided into management units as shown in Figure 12. The management units within each Land Office are as follows:

- Northwestern Land Office: Kalispell (KAL), Libby (LIB), Plains (PLN), Stillwater (STW), and Swan (SWN)
- Southwestern Land Office: Anaconda (ANA), Clearwater (CLW), Hamilton (HAM), and Missoula (MSO)
- Central Land Office: Bozeman (BOZ), Conrad (CON), Dillon (DIL), and Helena (HEL)

[27] Commercial acres exclude road clearings, hardwood stands, non-commercial conifer stands, and surface water.

- Eastern Land Office: Billings (BIL), Glasgow (GLA), Havre (HAV), Lewiston (LEW), and Miles City (MIL)

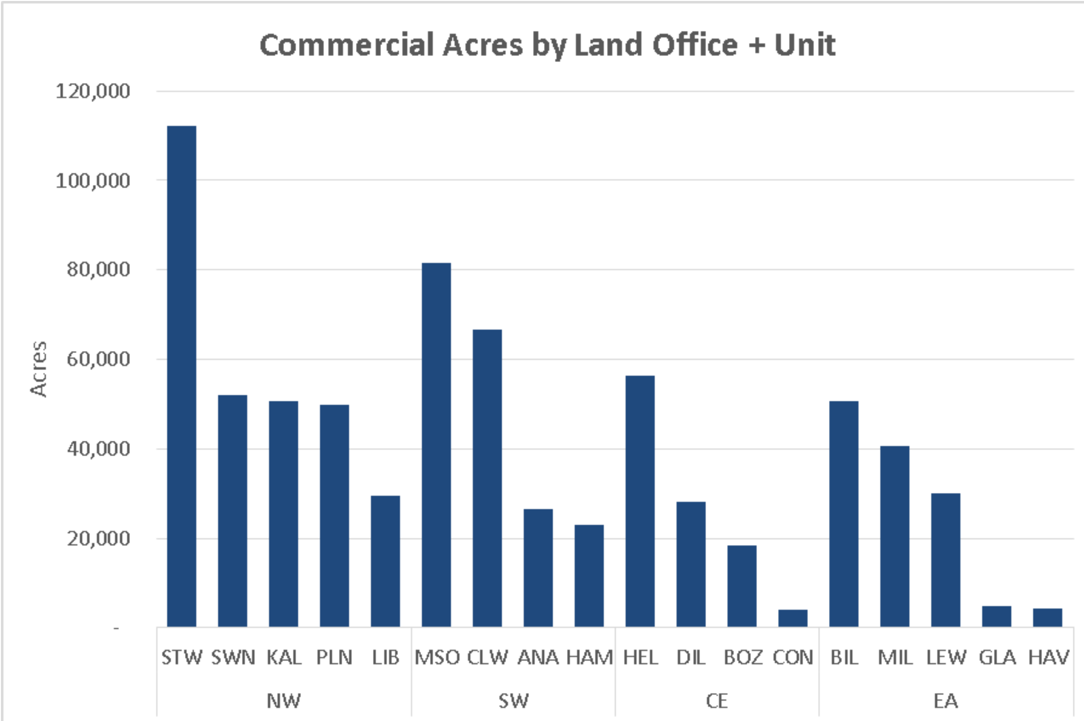


Figure 12: Commercial Acres of DNRC Forest Land by Land Office and Management Unit

In the Northwestern Land Office, the Stillwater Unit contains the most commercial acres of any other unit – about 112,000 acres. The Swan, Kalispell, and Plains Units have approximately an even share of the acres and the Libby Unit has the least at 29,000 acres. The Missoula and Clearwater Units make up 75% of the Southwestern Land Office with 148,000 combined acres out of the 198,000 total acres in the Land Office.

The forest inventory on these commercial acres totals about 4.6 billion board feet. This inventory is distributed across each Land Office as shown in Figure 13.

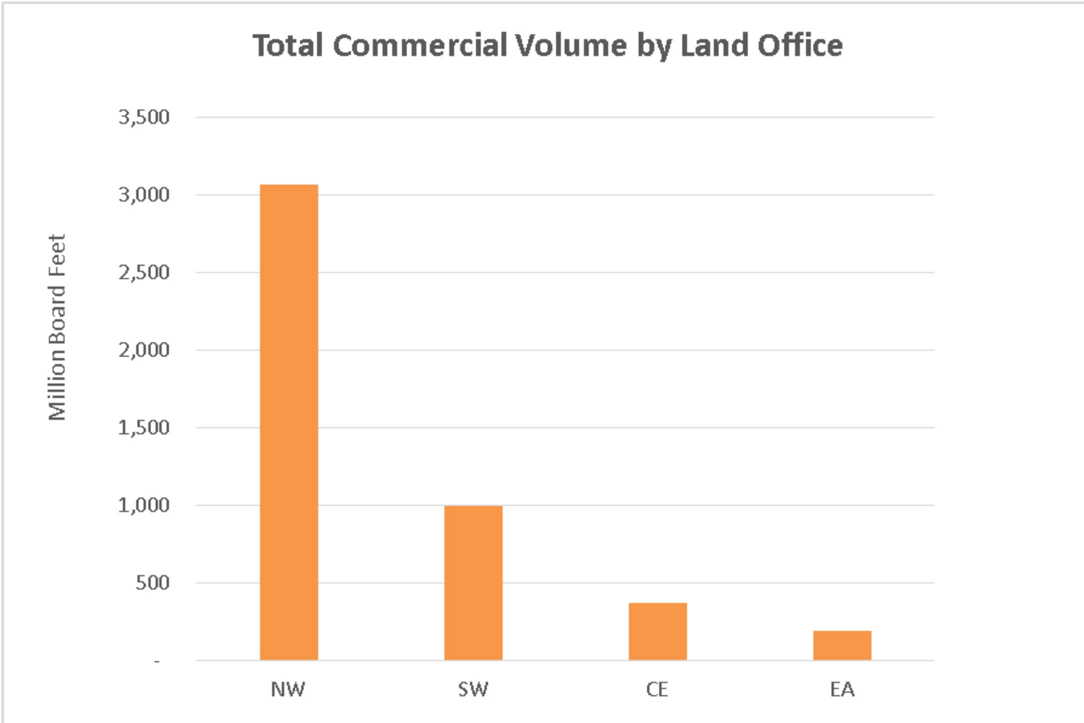


Figure 13: Total Volume on Commercial Acres by Land Office

The Northwestern Land Office contains about 66% of the total commercial volume of forest land across the entire state – 3.1 billion board feet. The Southwestern Land Office follows with about 998 million board feet (22%) and the Central and Eastern Land Offices have a combined total of 558 million board feet (12%).

Figure 14 shows the distribution of the commercial volume across each Land Office and Management Unit. The volumes are closely correlated to the acre distribution shown in Figure 12, above. The Stillwater Unit in the Northwestern Land Office has about 25% of the total commercial volume in the state while the other units make up another 41% of the statewide timber volume. In the Southwestern Land Office, the Missoula and Clearwater units contain about 78% (774 million board feet) of the volume in that Land Office.

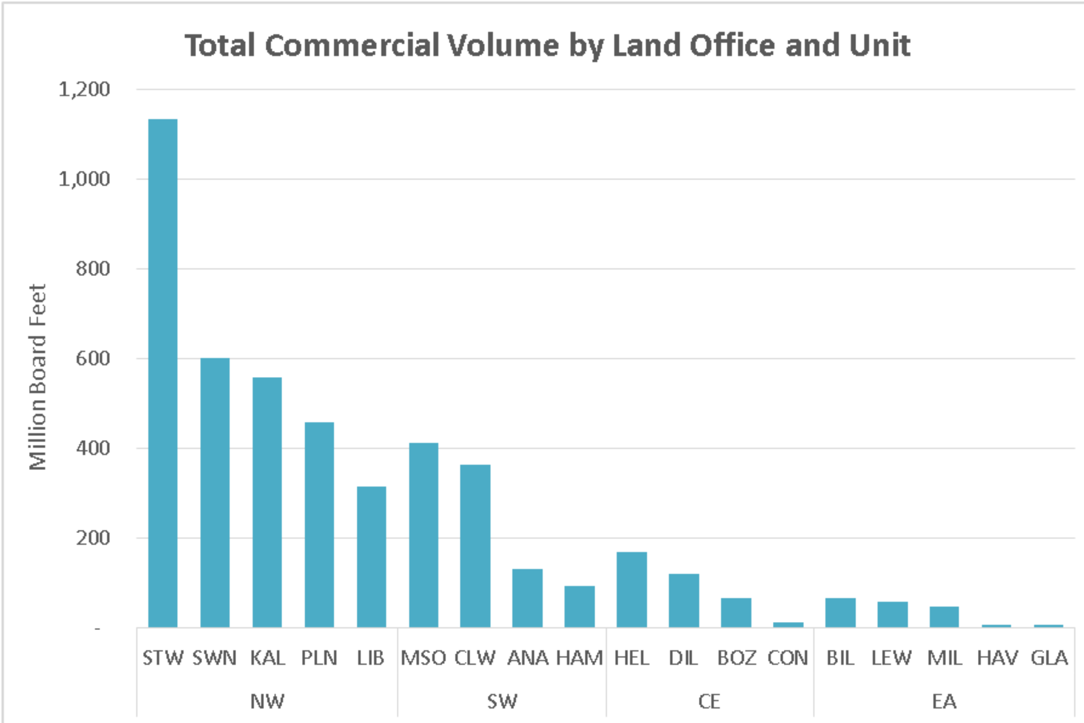


Figure 14: Total Volume on Commercial Acres by Land Office and Management Unit

The species distribution across the state is largely dominated by Douglas-fir (37%), western larch (18%), ponderosa pine (13%), and Engelmann spruce (10%). These species combined total about 3.6 billion board feet leaving 1 billion board feet of volume to other minor species such as subalpine fir, lodgepole pine, western redcedar, grand fir, and western hemlock. Figure 15 shows the species distribution across the state by Land Office – as can be expected, the Northwestern Land Office has the highest volume of any particular species except for ponderosa pine in the Southwestern Land Office. Table 30 below, shows the species code and full species name for reference purposes.

Table 30: Species codes and names

Species Code	Species Name
AF	Subalpine Fir
AL	Subalpine Larch
AS	Aspen
BC	Cottonwood Species
DF	Douglas-Fir
ES	Engelmann Spruce
GF	Grand Fir
JU	Juniper Species
LP	Lodgepole Pine
MH	Mountain Hemlock

Species Code	Species Name
OH	Misc. Hardwoods
PB	Paper Birch
PF	Limber Pine
PP	Ponderosa Pine
RC	Western Redcedar
WB	Whitebark Pine
WH	Western Hemlock
WL	Western Larch
WP	Western White Pine

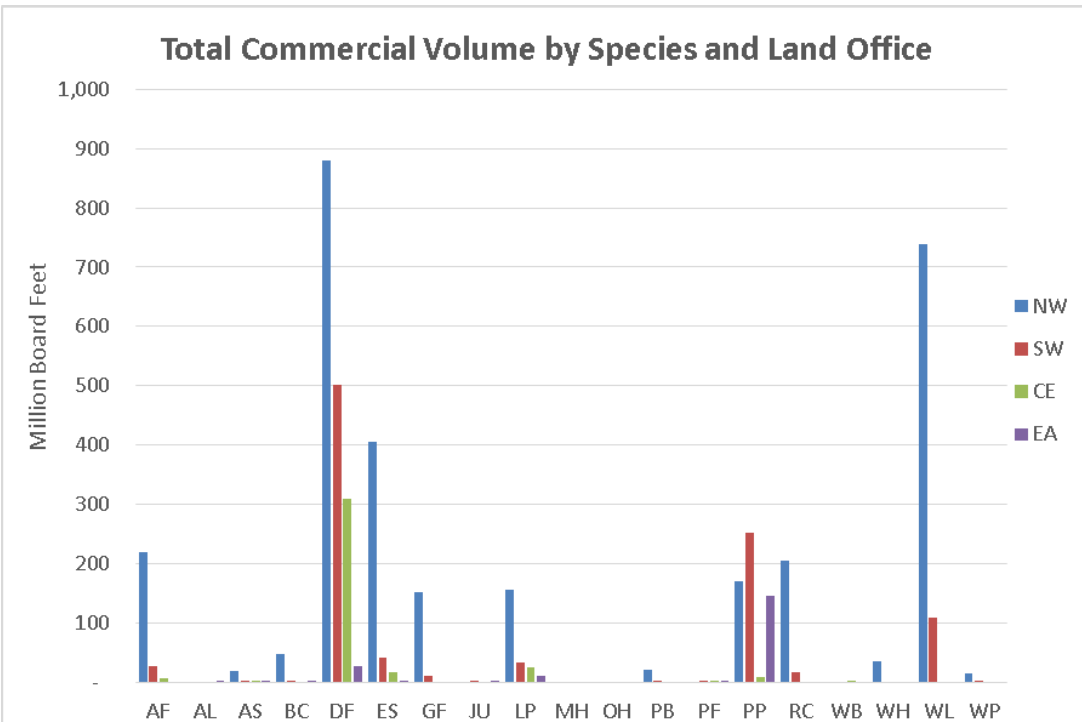


Figure 15: Total Volume on Commercial Acres by Species and Land Office

Site productivity across the state differs by Land Office and determines the relative growth potential of trees in a particular stand. The DNRC's stand level inventory provides the site productivity value of each stand which relates the annual tree growth in terms of cubic feet per acre per year. These numbers are then grouped into classes, as shown below in Table 31.

Table 31: Site Productivity and Site Class by Land Office

Land Office	Low (L)	Medium (M)	High (H)
NW	35	55	70
SW	35	55	65
CE	40	-	50
EA	30	-	-

As shown in Figure 16 and Figure 17, the Northwestern Land Office has the largest number of acres and total volume on sites with high productivity across the state. The Central Land Office is dominated by high and low site productivity while the Eastern Land Office is entirely low site ground.

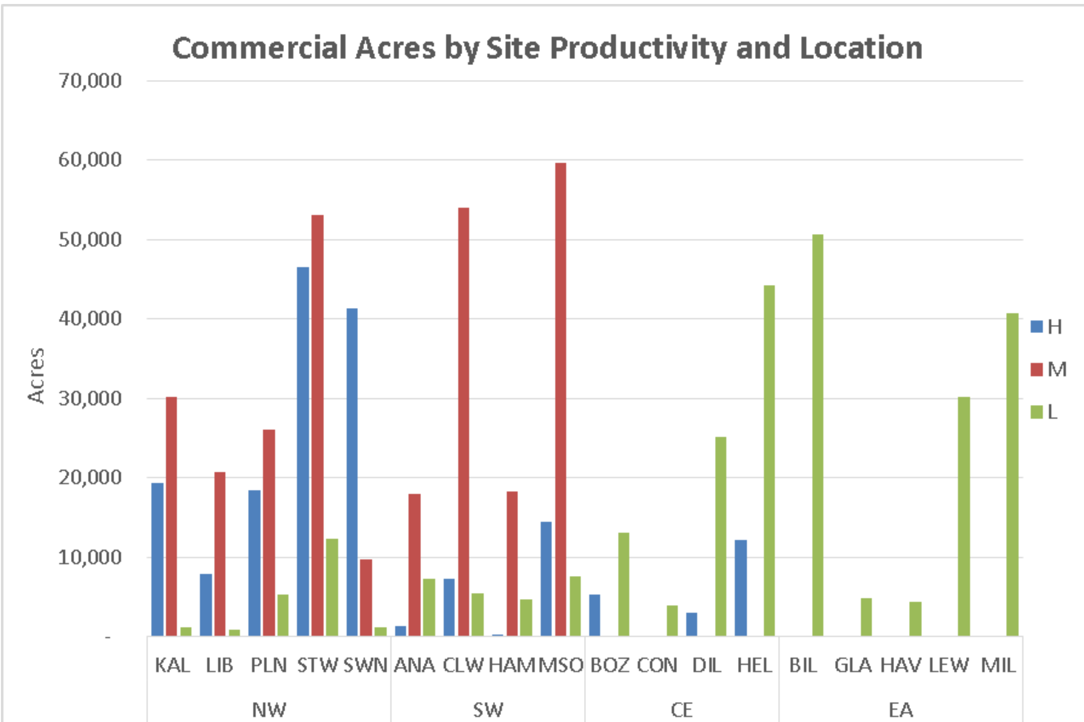


Figure 16: Commercial Acres by Site Productivity Class

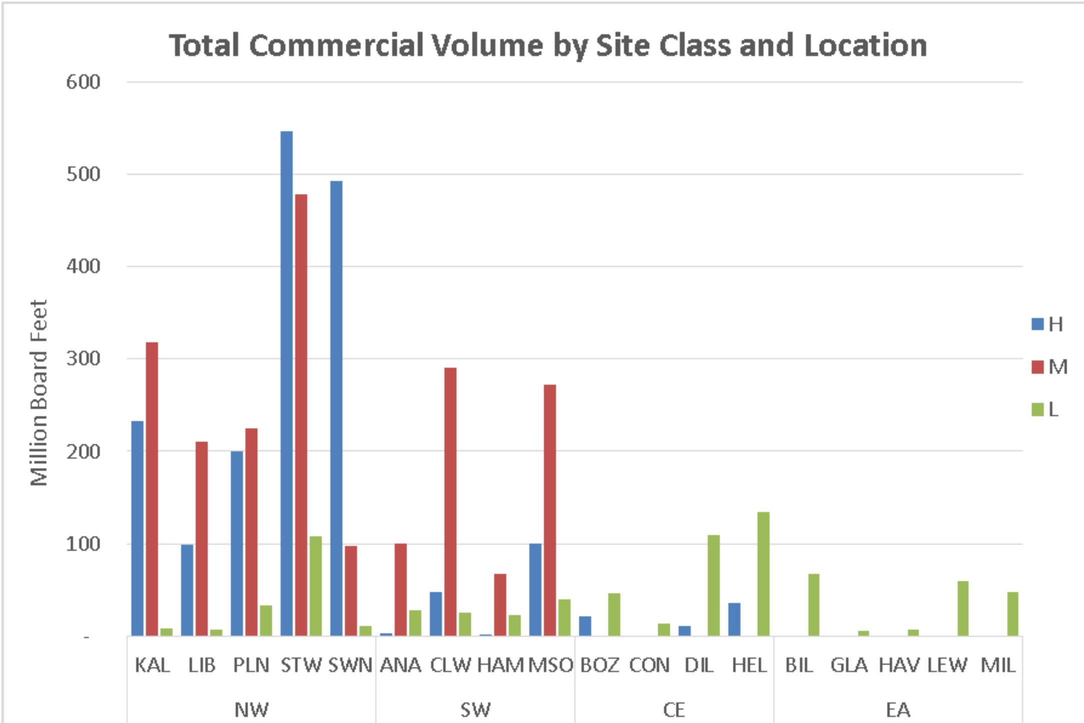


Figure 17: Total Volume on Commercial Acres by Site Productivity Class

Across the entire state, the volume of merchantable trees (DBH greater than 4”) is dominated by those in the 8” DBH to 15.9” DBH range – almost 99% of the volume falls within this range. Only 1% of the volume is in trees greater than 16” DBH or less than 8” DBH. Figure 18 and Figure 19 below show the size class distribution (acres and volume) for the entire state by Land Office and Management Unit.

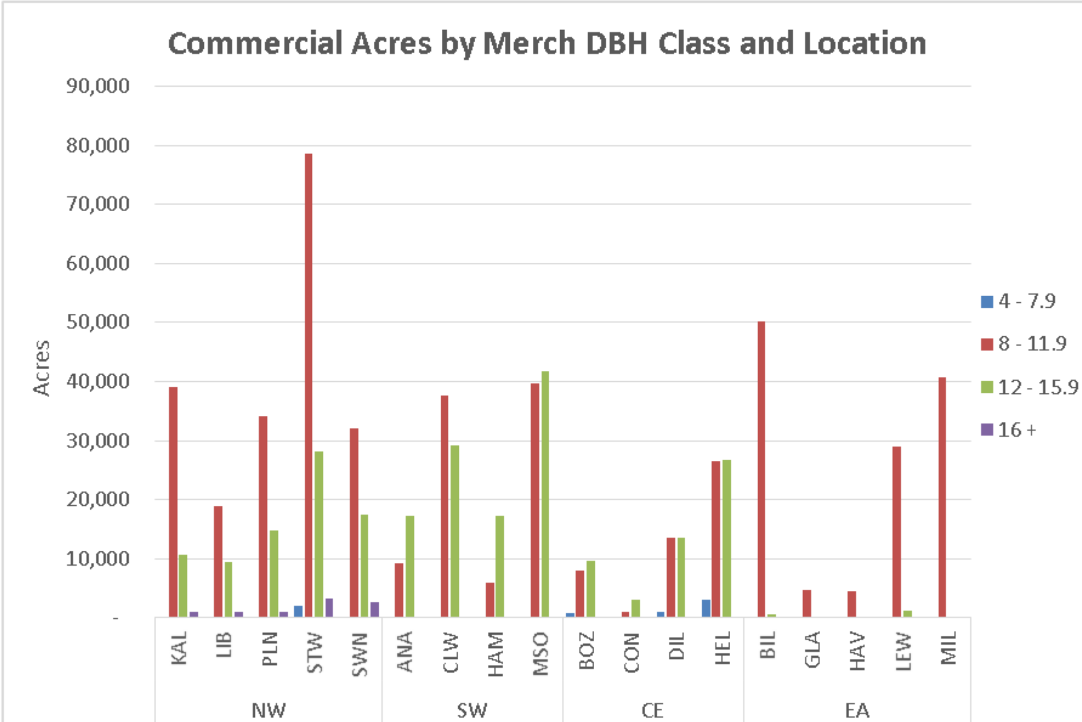


Figure 18: Commercial Acres by Size Class

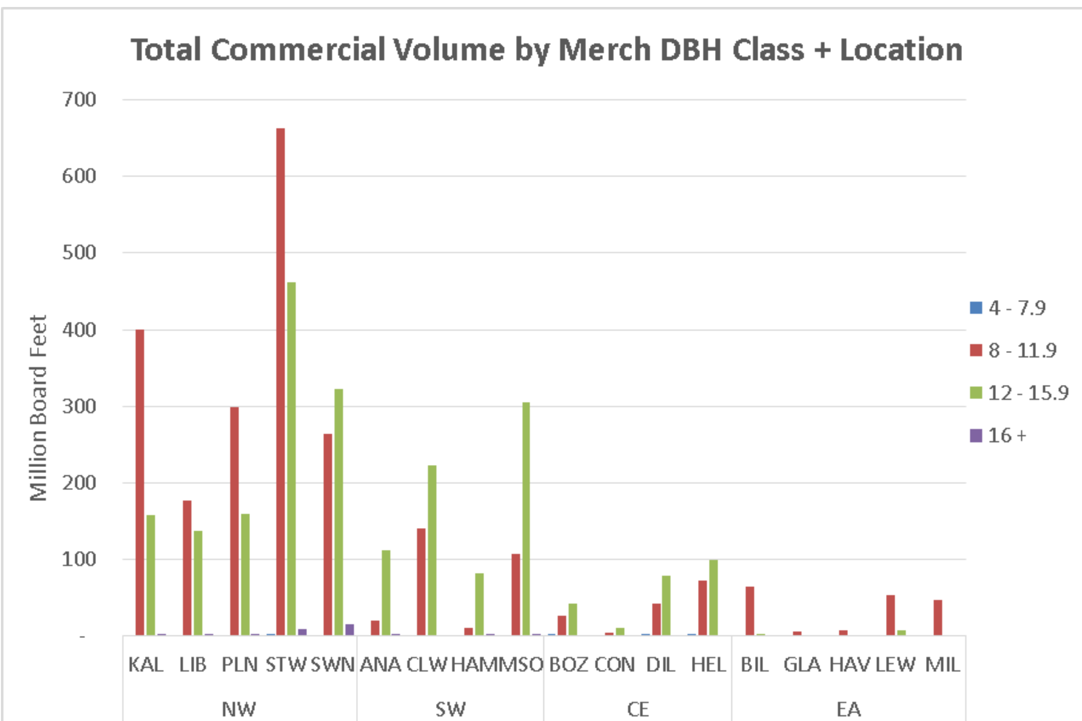


Figure 19: Total Volume on Commercial Acres by Size Class

Commercial acres and volume by stocking class are shown in Figure 20 and Figure 21. For the purpose of this project, stocking was defined by the saw-timber stocking code (>9" DBH for conifers and >11” DBH for hardwoods). The stocking code relates the percentage of crown density in a stand defined by the following classes:

- W = well stocking with >=70% crown density
- M = medium stocking with 40 – 69% crown density
- P = poor stocking with 10 – 39% crown density
- N = no stocking or scattered stocking with <=10% crown density

The Northwestern Land Office has an even distribution of acres across stocking classes while 47% of the volume is in medium stocked stands. Acres in the Southwestern Land Office are heavily distributed towards medium and poorly stocked stands, but 54% of the areas volume is in medium stocked stands. The remaining Land Offices have most of their acres and volume distributed across the medium and poorly stocked stands.

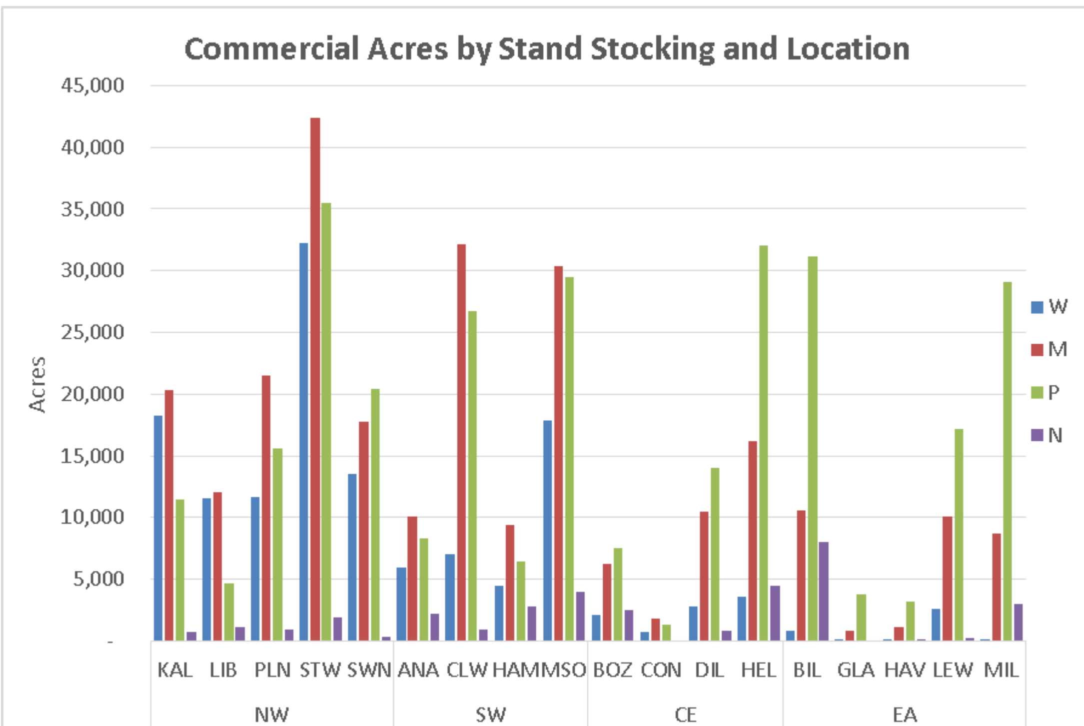


Figure 20: Commercial Acres by Stand Stocking

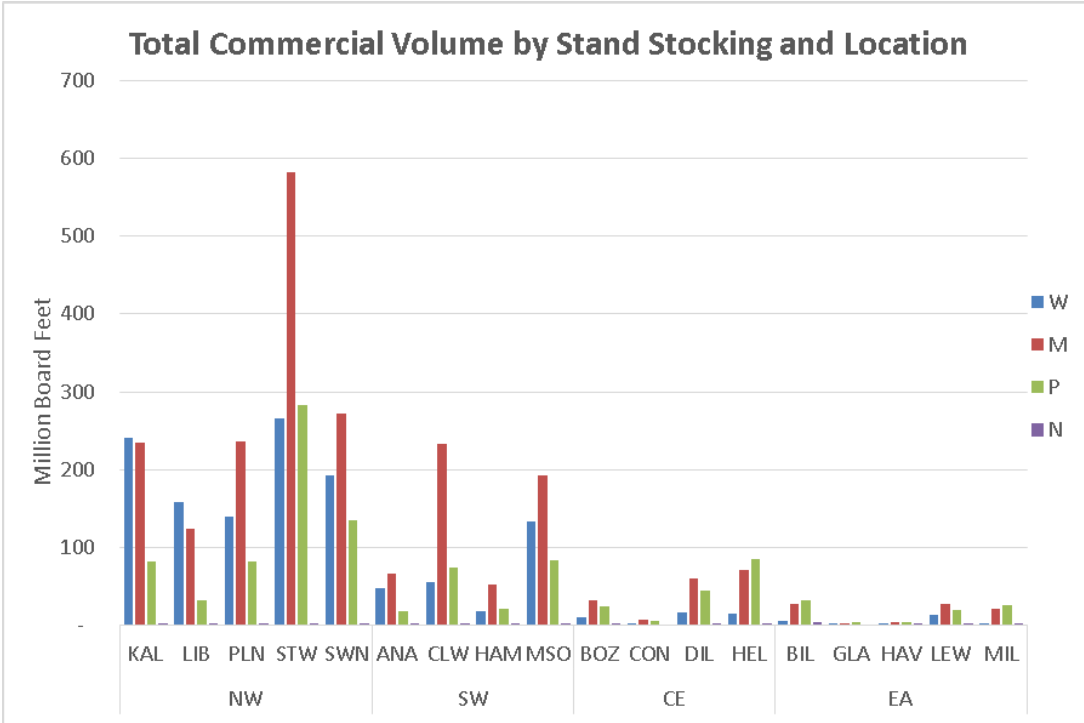


Figure 21: Total Volume on Commercial Acres by Stand Stocking

Stand stocking in terms of trees per acre (TPA) is shown in Figure 22 and Figure 23 for each Land Office and Management Unit. In general, stands in the Northwestern and Southwestern Land Offices have higher TPA stocking than in the Central and Eastern Land Offices.

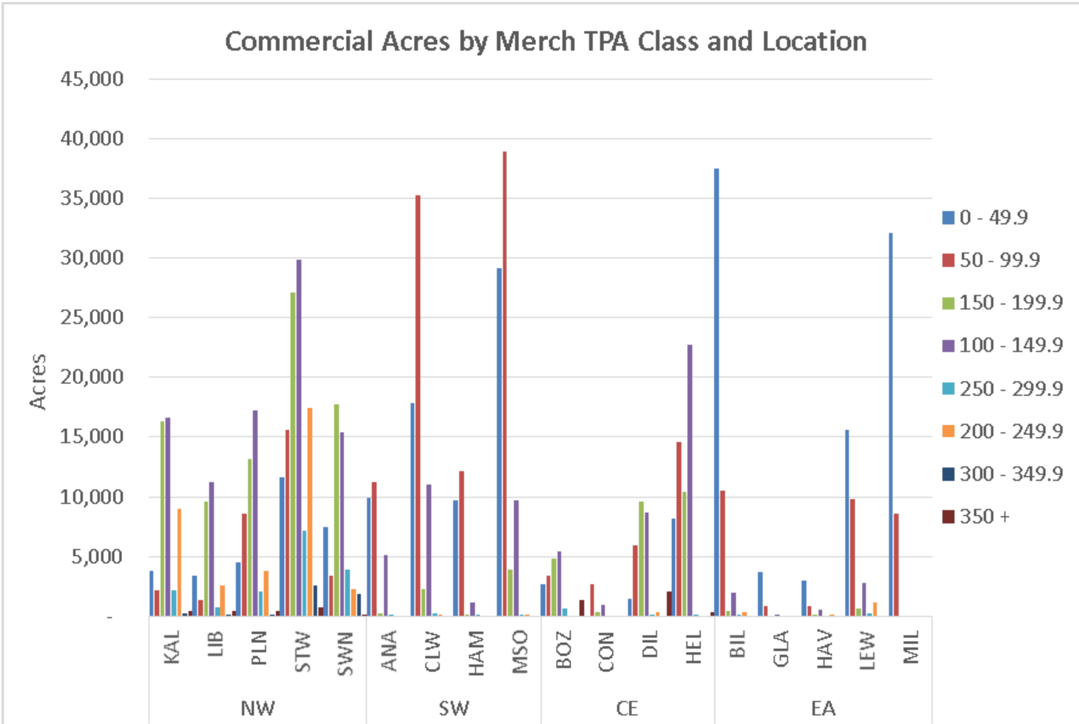


Figure 22: Commercial Acres by Trees per Acre of Merchantable Trees

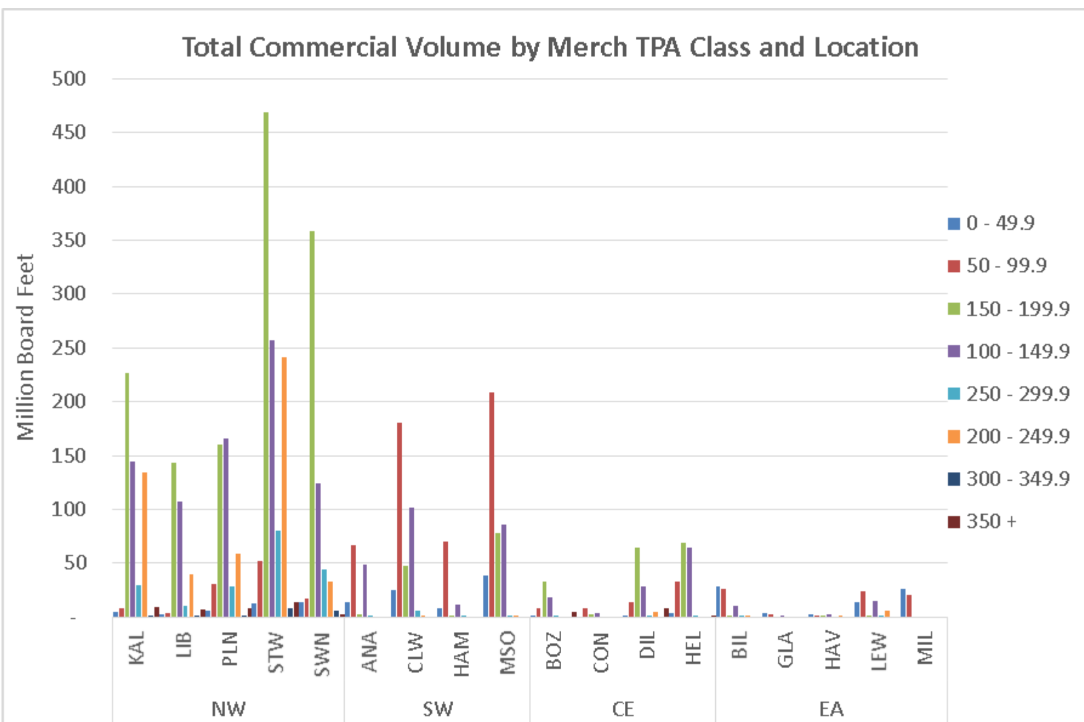


Figure 23: Total Volume on Commercial Acres by Trees per Acre of Merchantable Tree

19 Appendix L: Selected yield tables for NW, SW, CE, and EA

The following section contains an extract of the growth and yield tables prepared for this sustainable yield calculation. Four strata groups are included as representative types across the DNRC. These are, Douglas-fir/Larch mix for the Northwestern land office (NW-DL), Douglas-fir for the Southwestern land office (SW-D), Douglas-fir for the central land office (CE-D), and Ponderosa Pine for the eastern land office (EA-P). Yield table development for each group is shown through three charts, representing modeled growth compared against measured data, inventory development for various management pathways, and harvest volume levels for various management pathways.

19.1 NW-DL

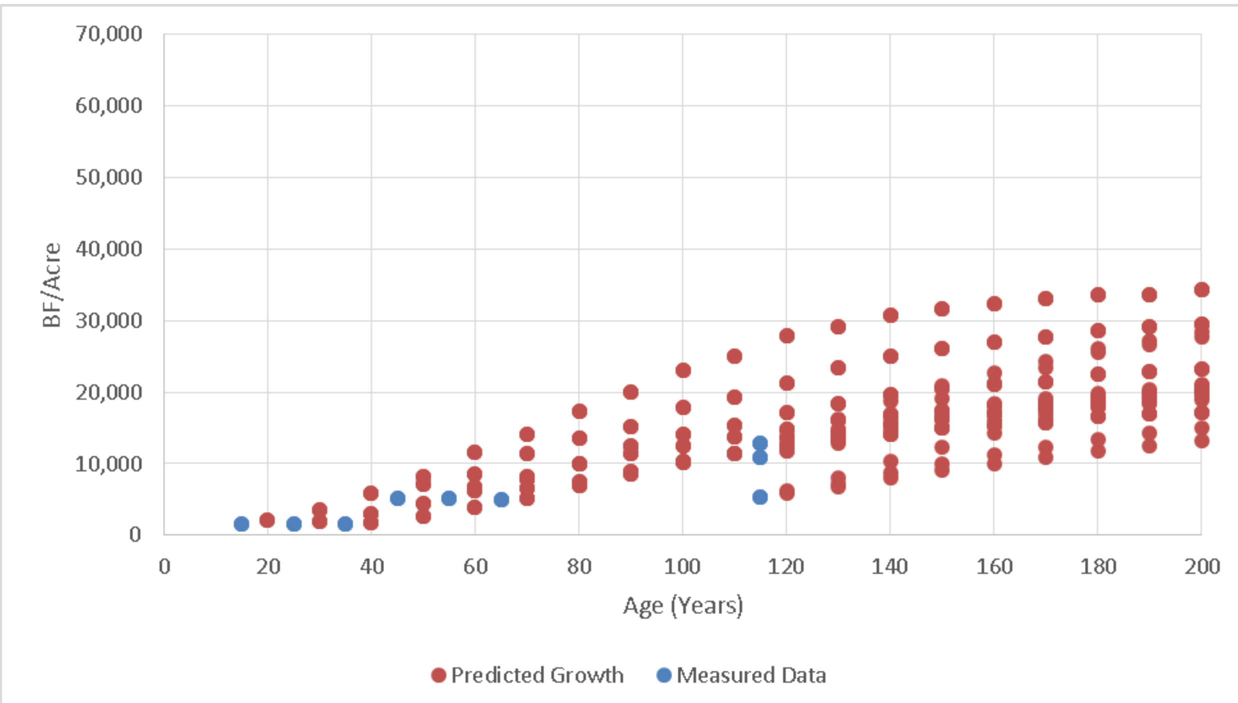


Figure 24: NW-DL Predicted Growth vs. Measured Data

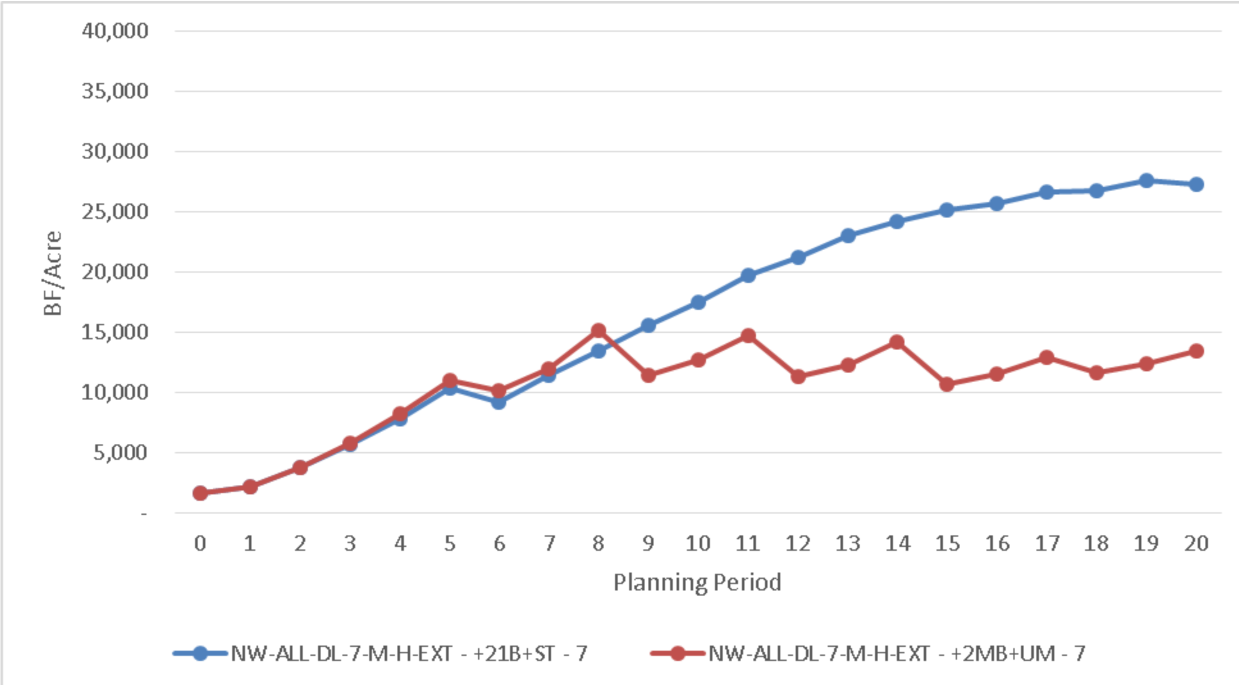


Figure 25: NW-DL Inventory per Period per Rx

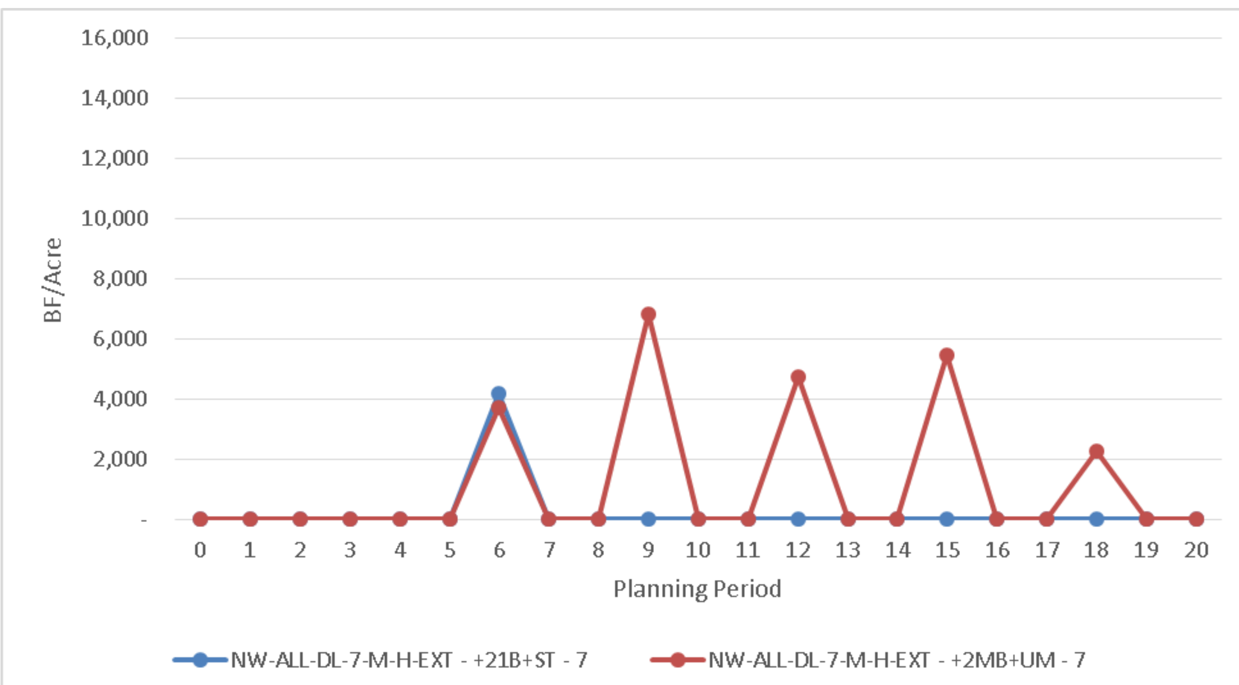


Figure 26: NW-DL Volume Harvested per Period per Rx

19.2 SW-D

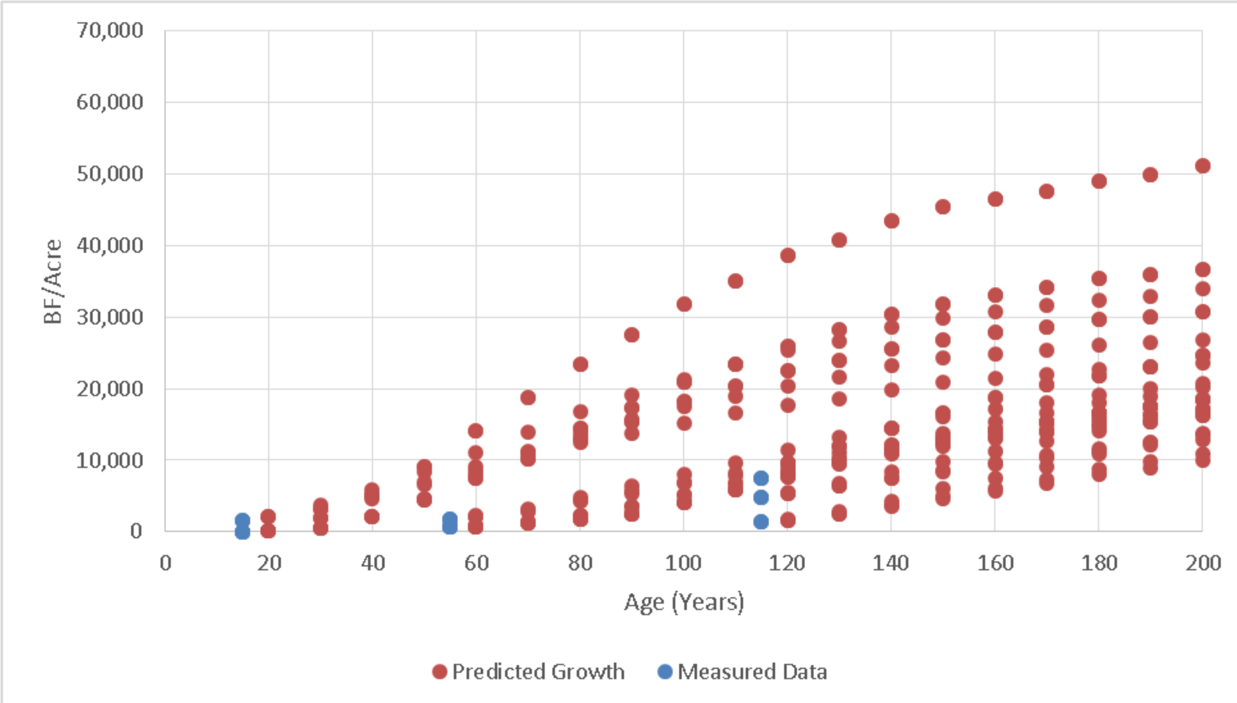


Figure 27: SW-D Predicted Growth vs. Measured Data

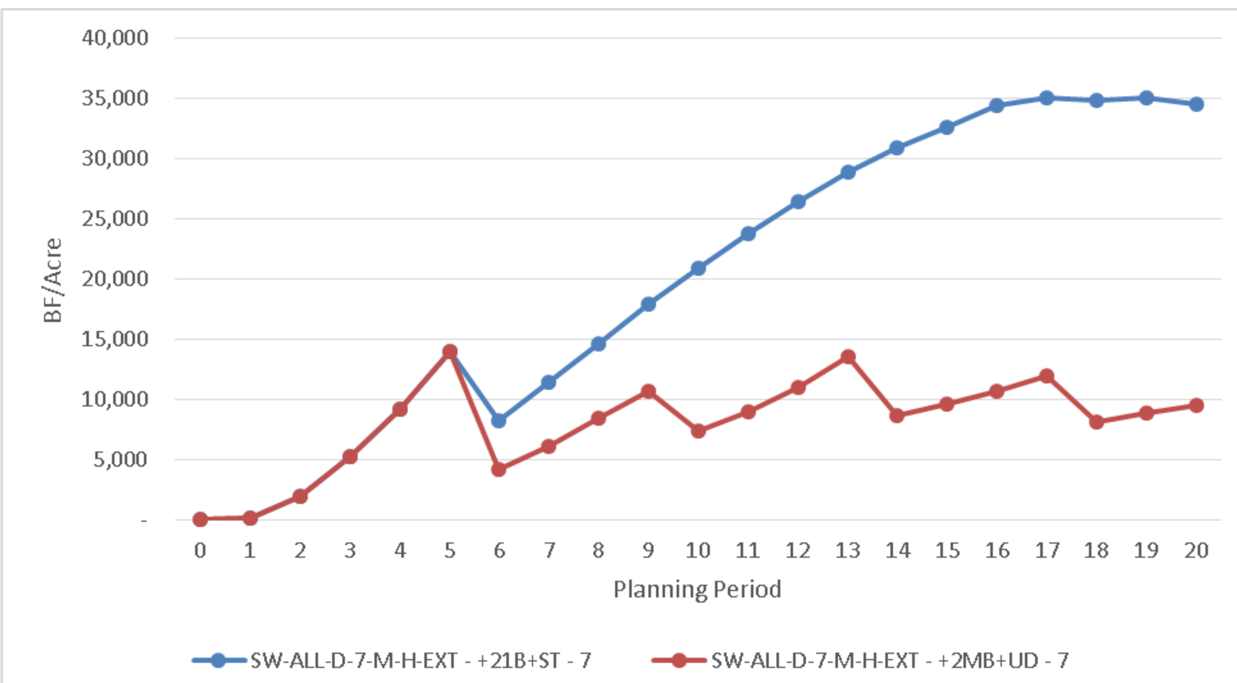


Figure 28: SW-D Inventory per Period per Rx

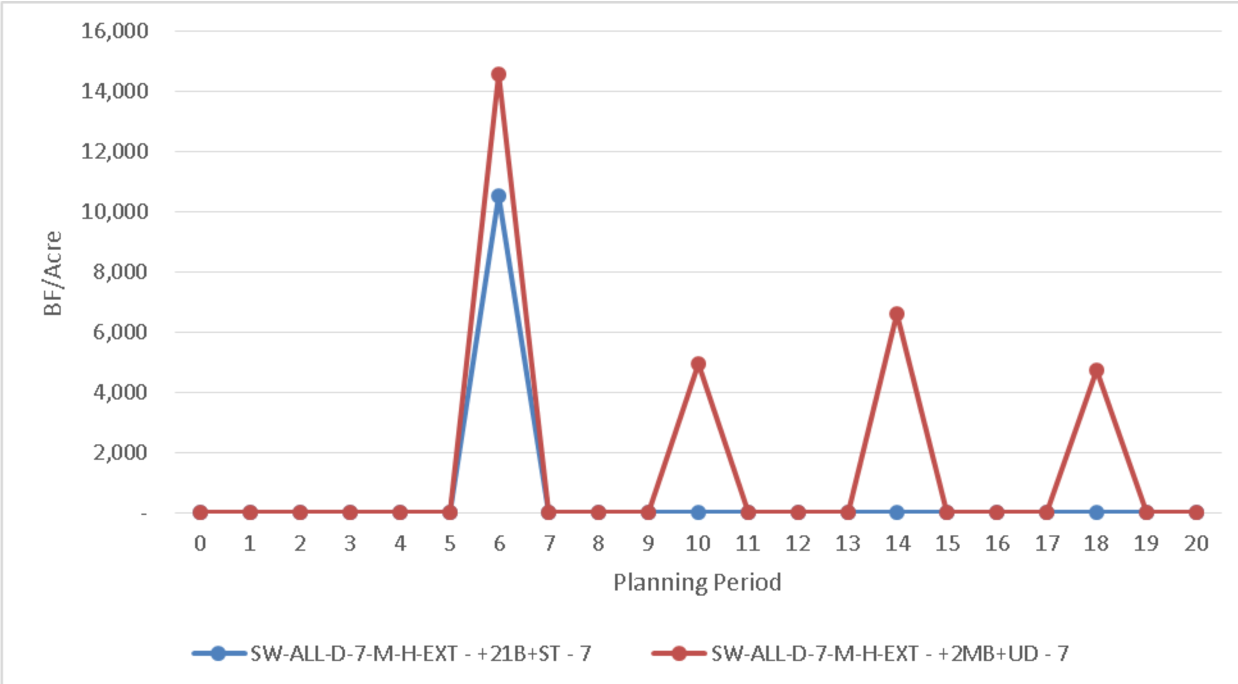


Figure 29: SW-D Volume Harvested per Period per Rx

19.3 CE-D

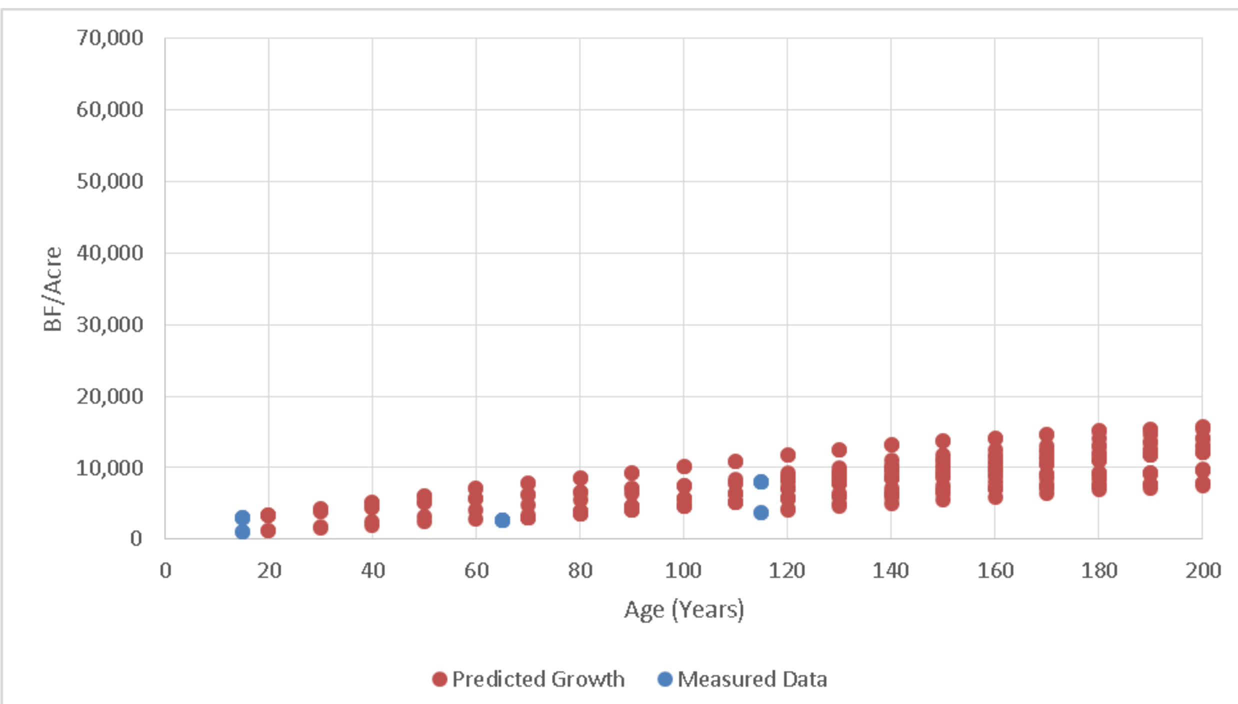


Figure 30: CE-D Predicted Growth vs. Measured Data

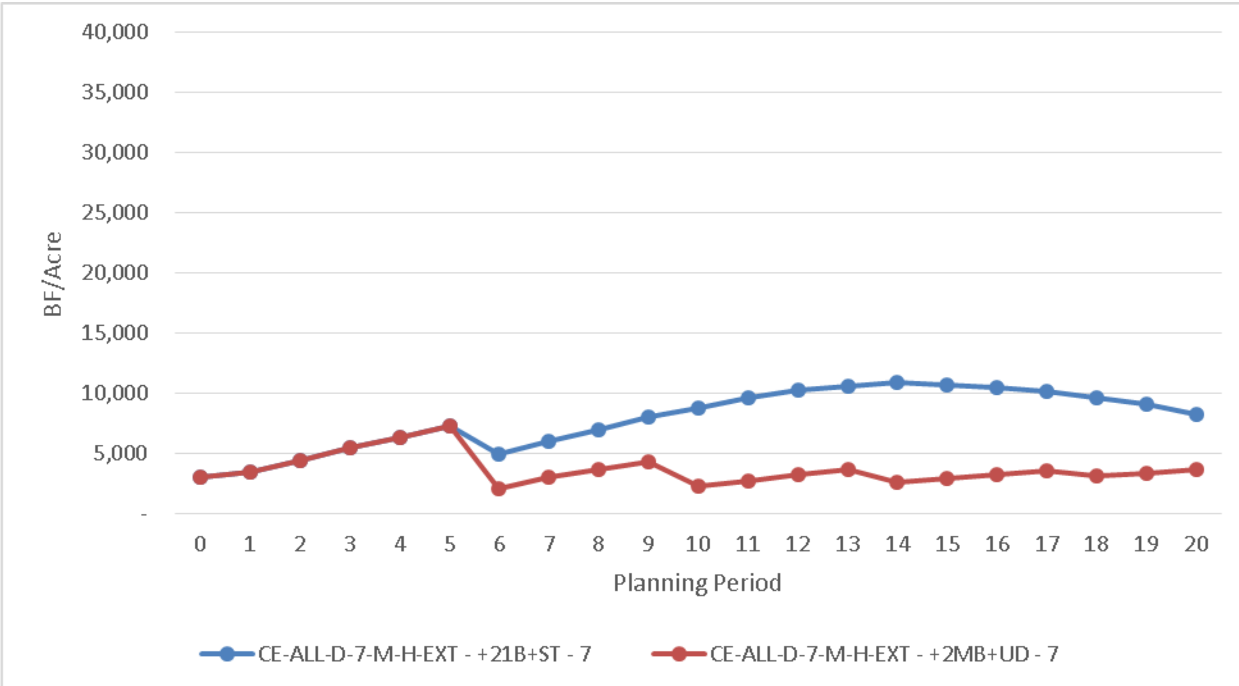


Figure 31: CE-D Inventory per Period per Rx

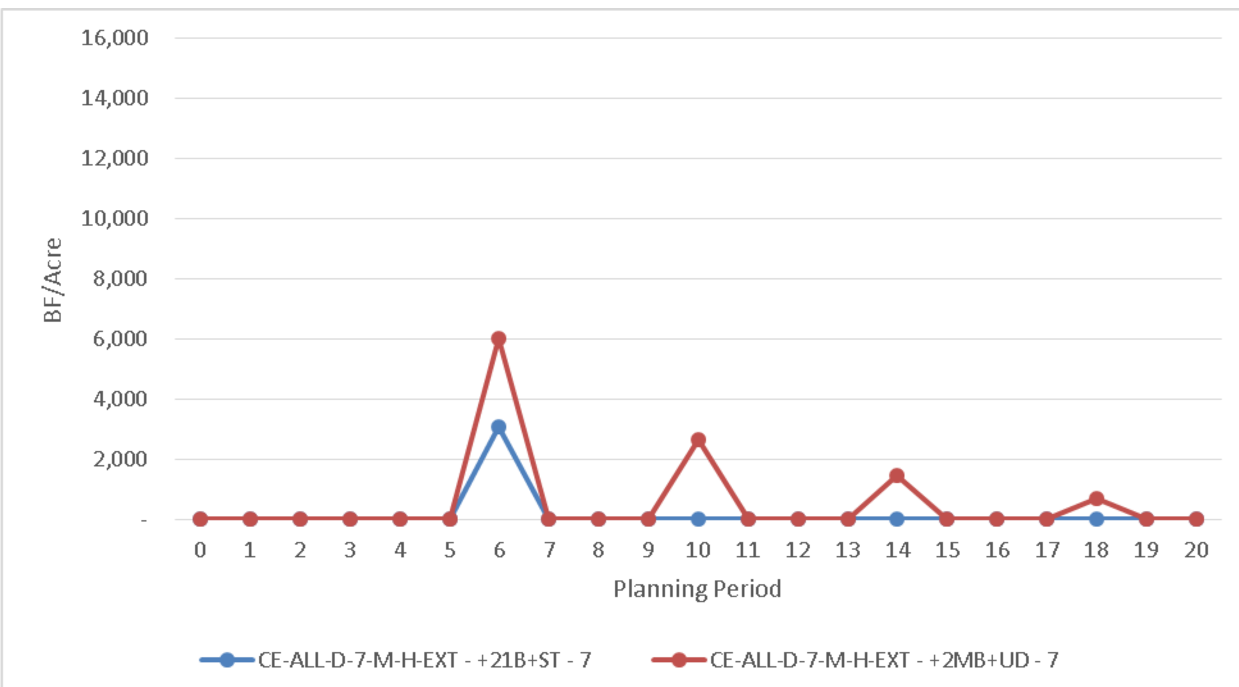


Figure 32: CE-D Volume Harvested per Period per Rx

19.4 EA-P

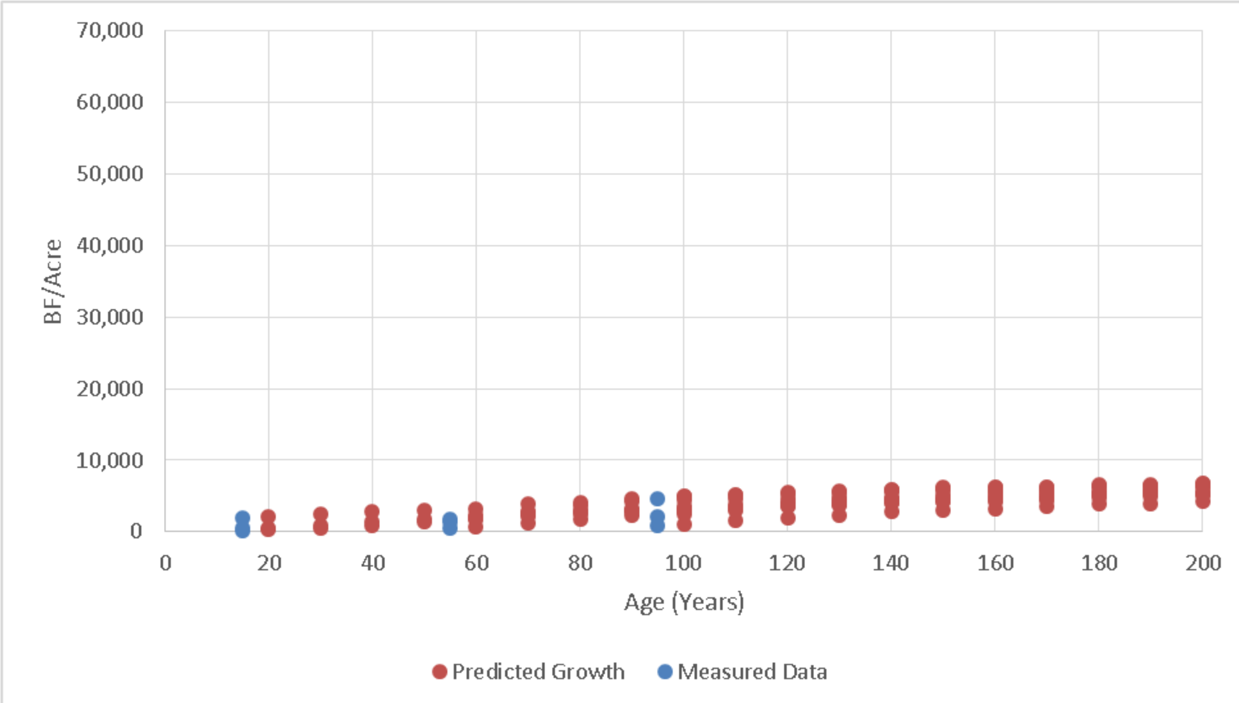


Figure 33: EA-P Predicted Growth vs. Measured Data

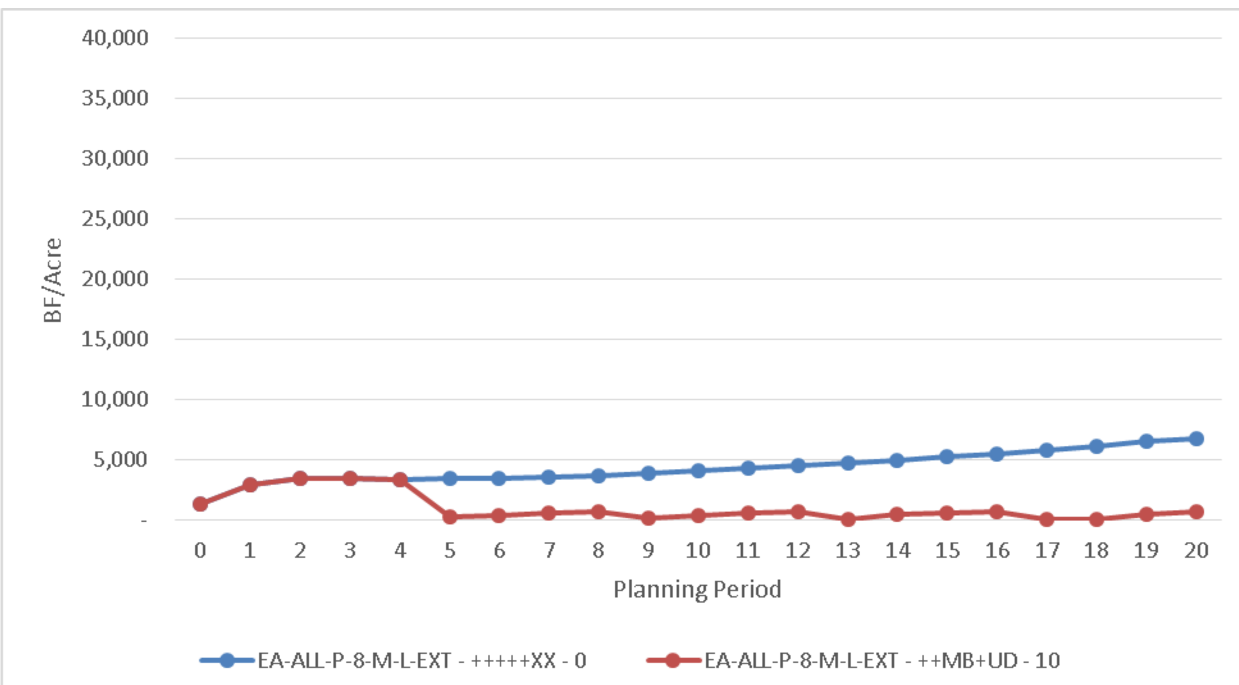


Figure 34: EA-P Inventory per Period per Rx

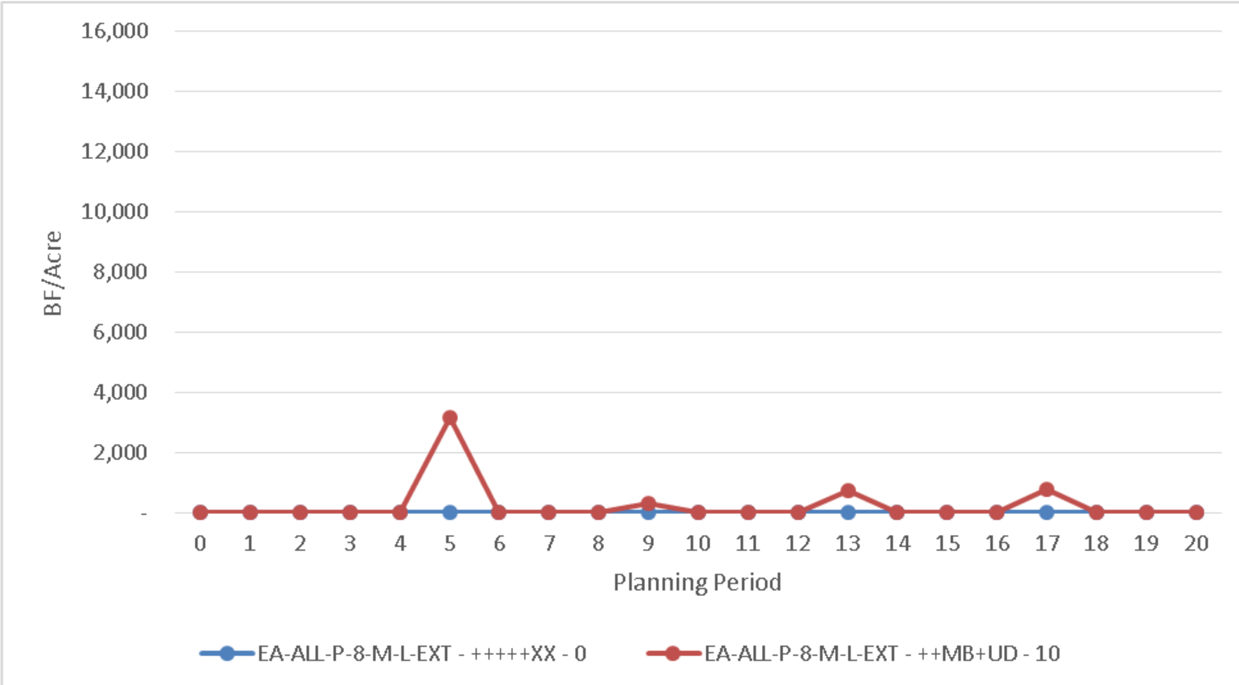


Figure 35: EA-P Volume Harvested per Period per Rx

20 Appendix M: Additional Model Results

20.1 Unconstrained Grizzly Bear Core Acres

The following charts show selected results from the final LP model run with unconstrained Grizzly Bear Core acres (active management allowed within the Core).

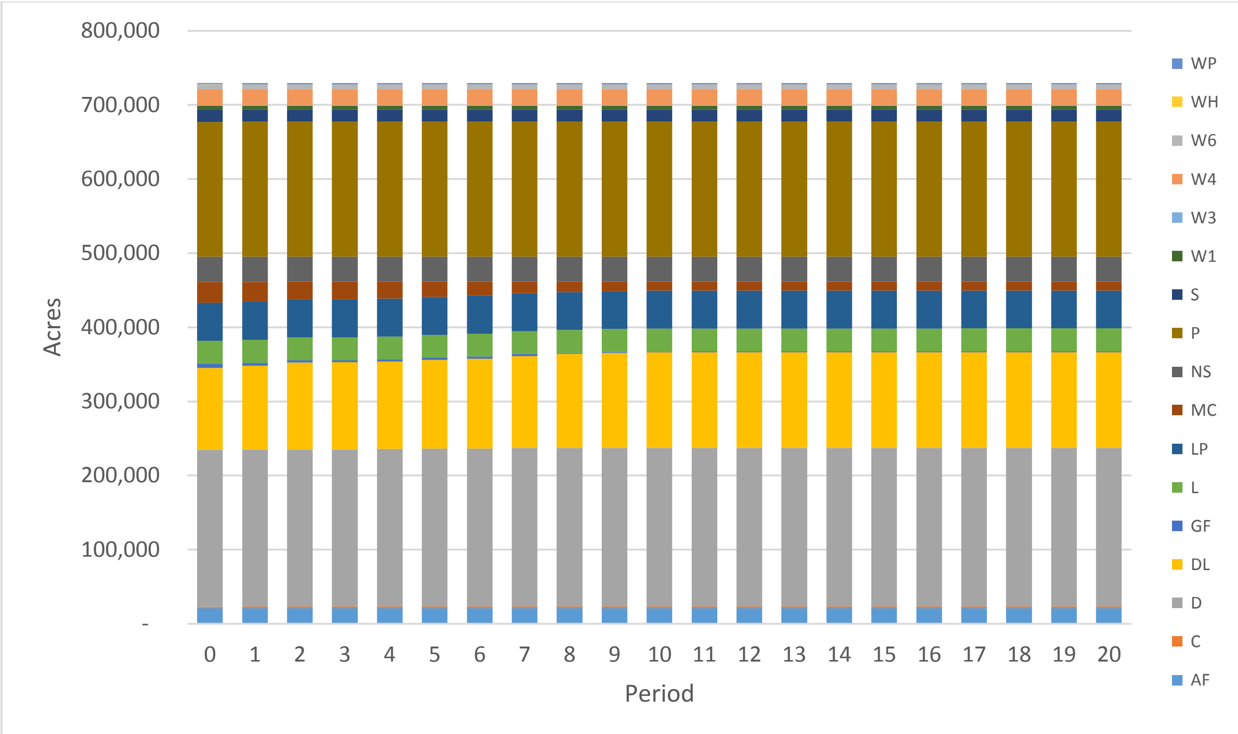


Figure 36: Acres by Species – Grizzly Bear Core Unconstrained

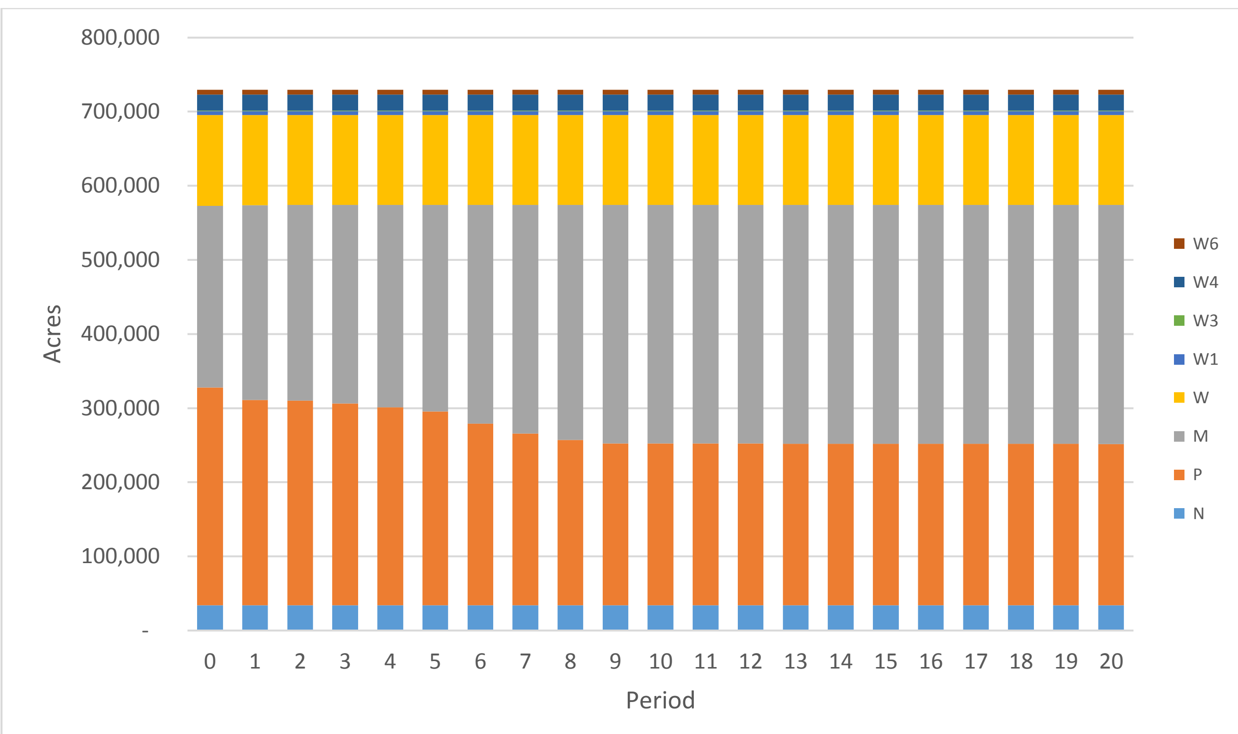


Figure 37: Acres by Stocking – Grizzly Bear Core Unconstrained

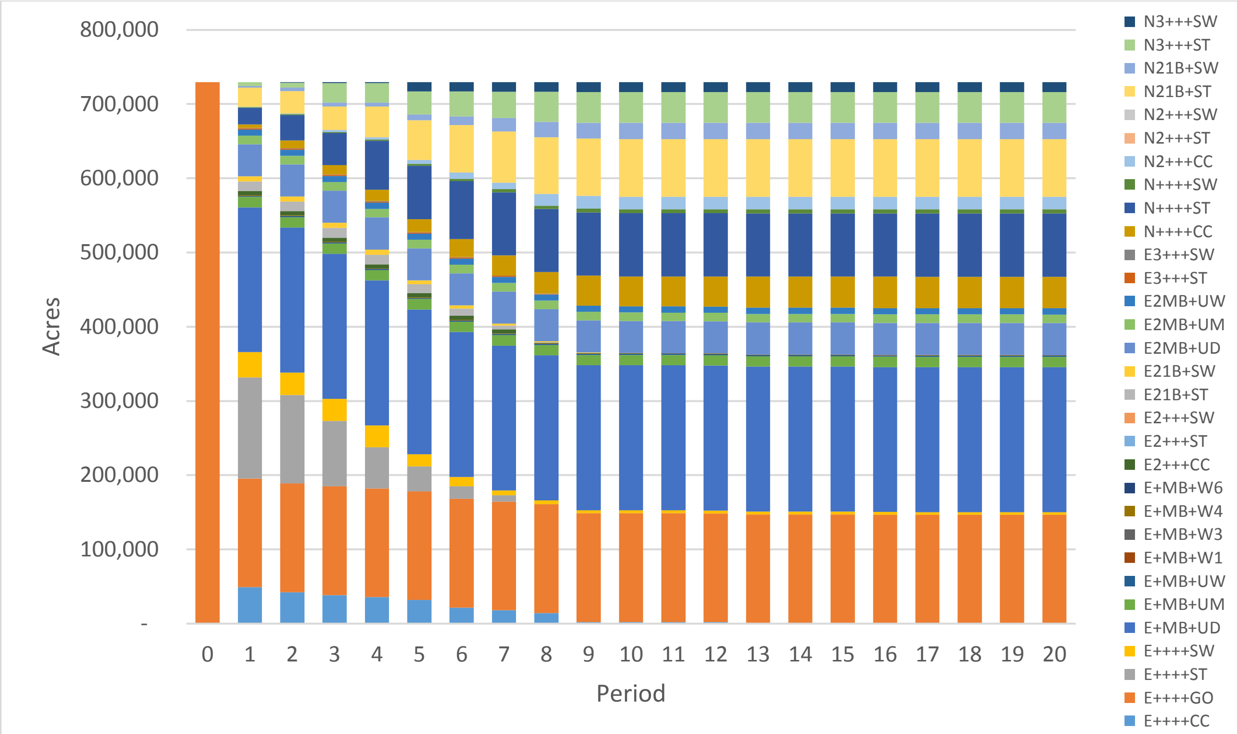


Figure 38: Management Pathway Acres – Grizzly Bear Core Unconstrained

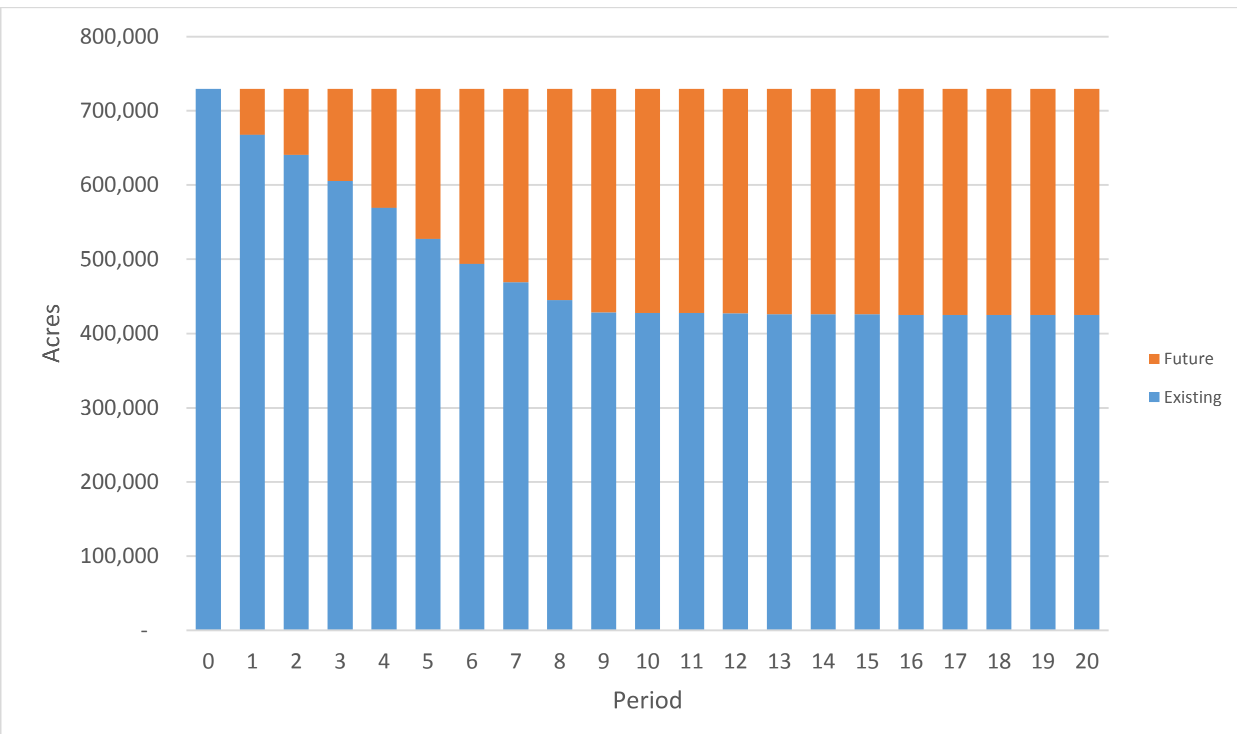


Figure 39: Existing vs. Future Rotation Acres – Grizzly Bear Core Unconstrained

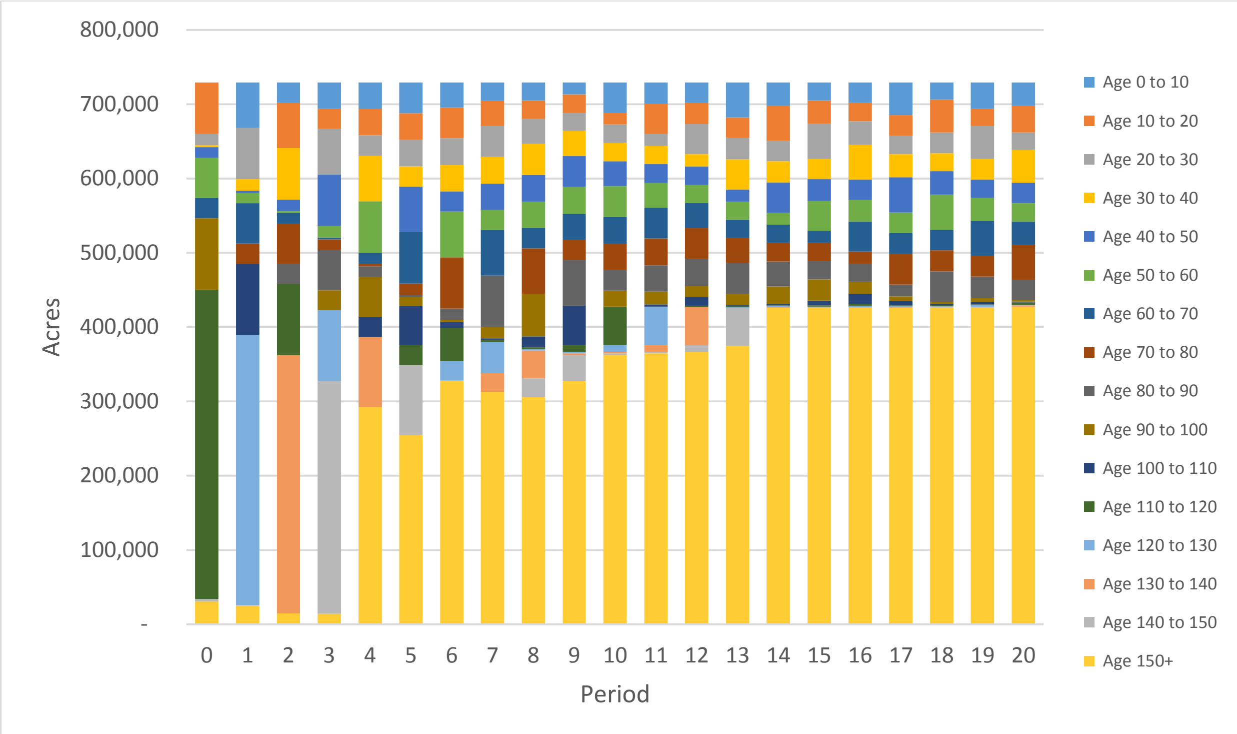


Figure 40: Age Class Distribution – Grizzly Bear Core Unconstrained

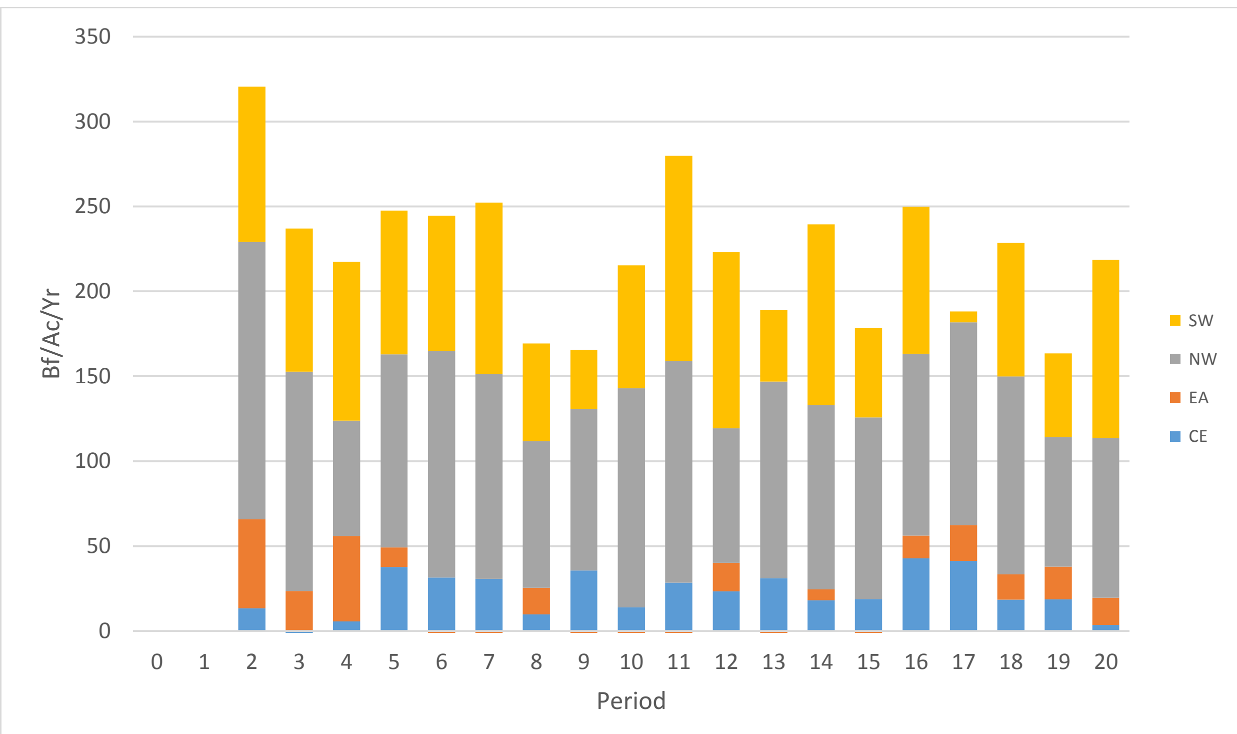


Figure 41: Average Annual Growth Rate – Grizzly Bear Core Unconstrained

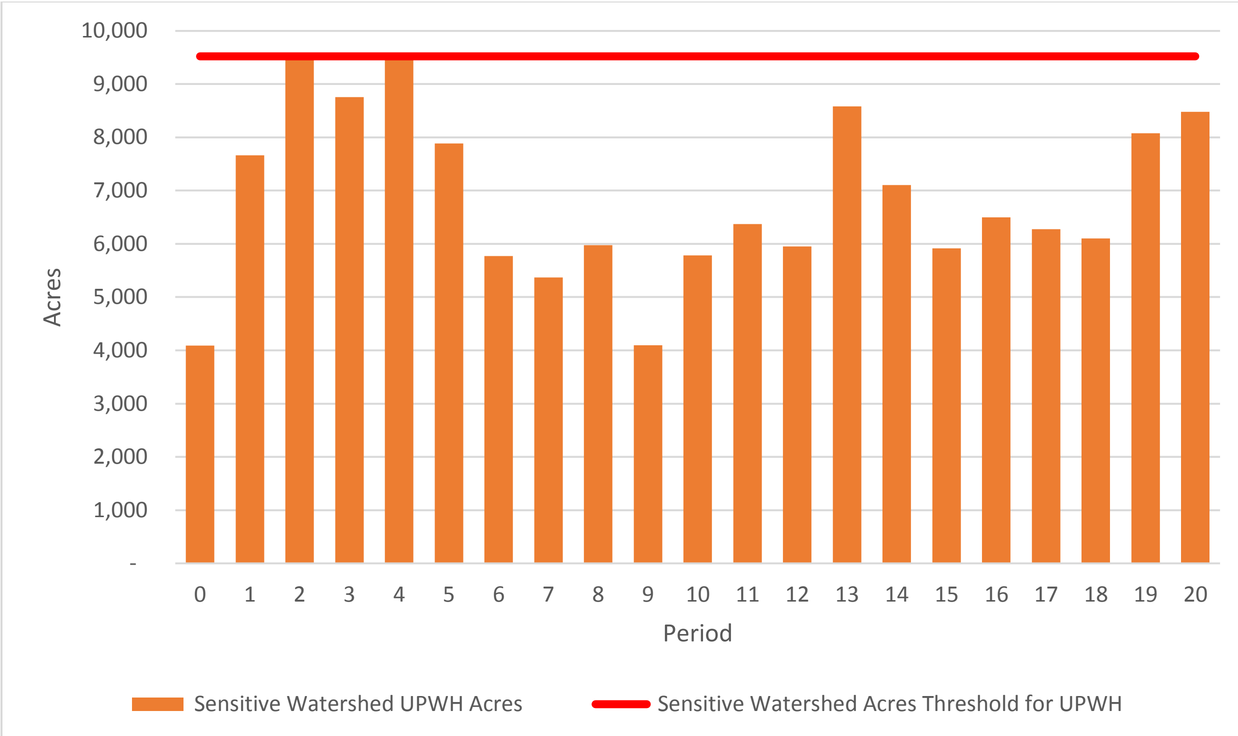


Figure 42: Sensitive Watershed Development (UPWH) – Grizzly Bear Core Unconstrained

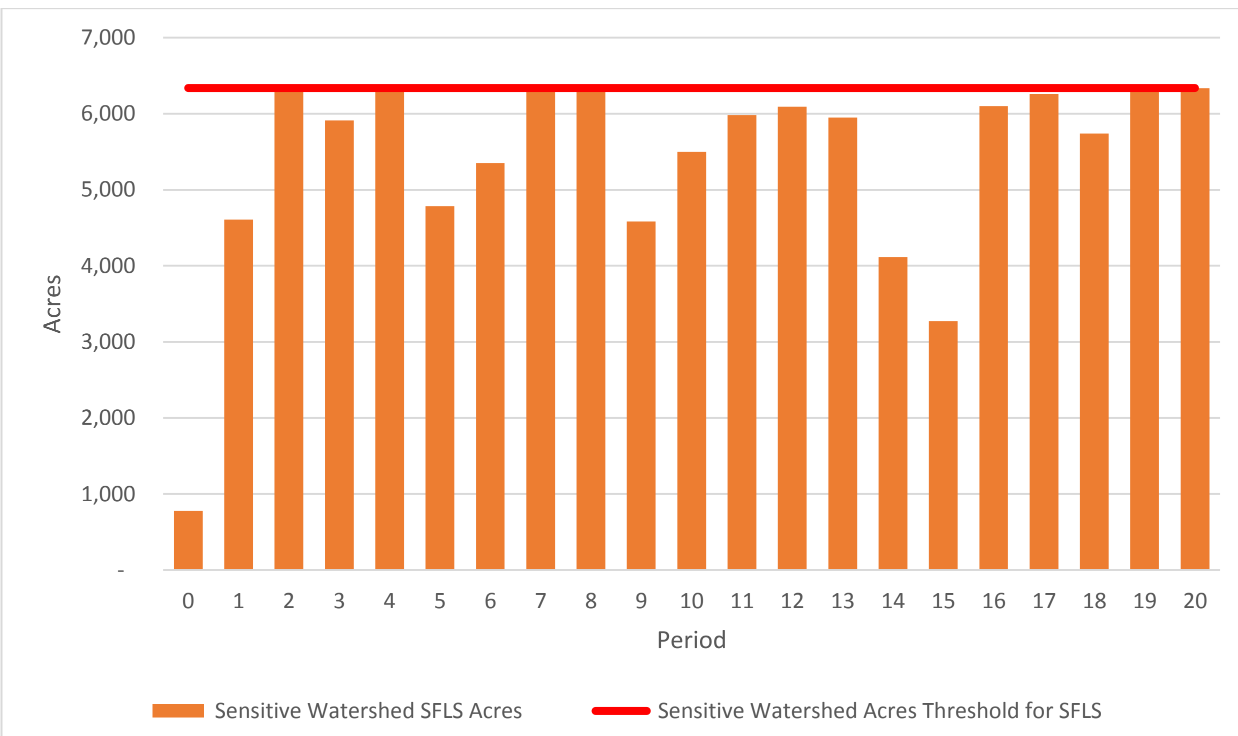


Figure 43: Sensitive Watershed Development (SFLS) – Grizzly Bear Core Unconstrained

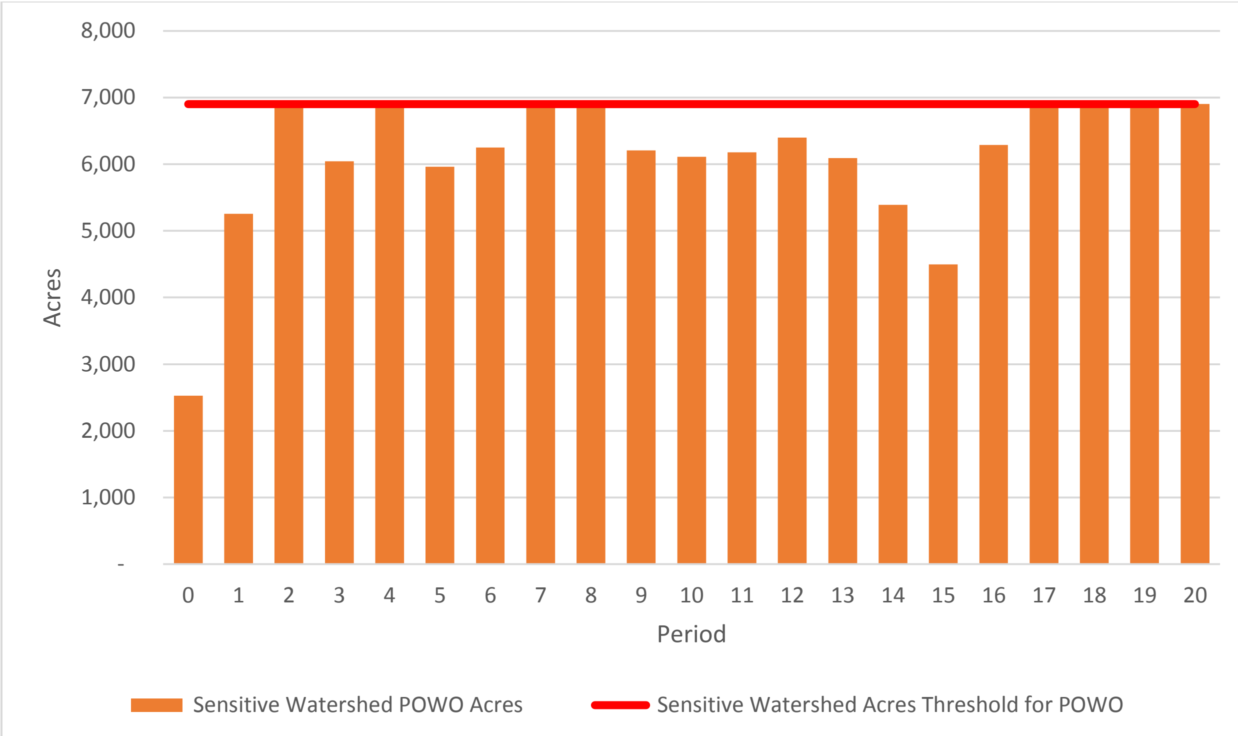


Figure 44: Sensitive Watershed Development (POWO) – Grizzly Bear Core Unconstrained

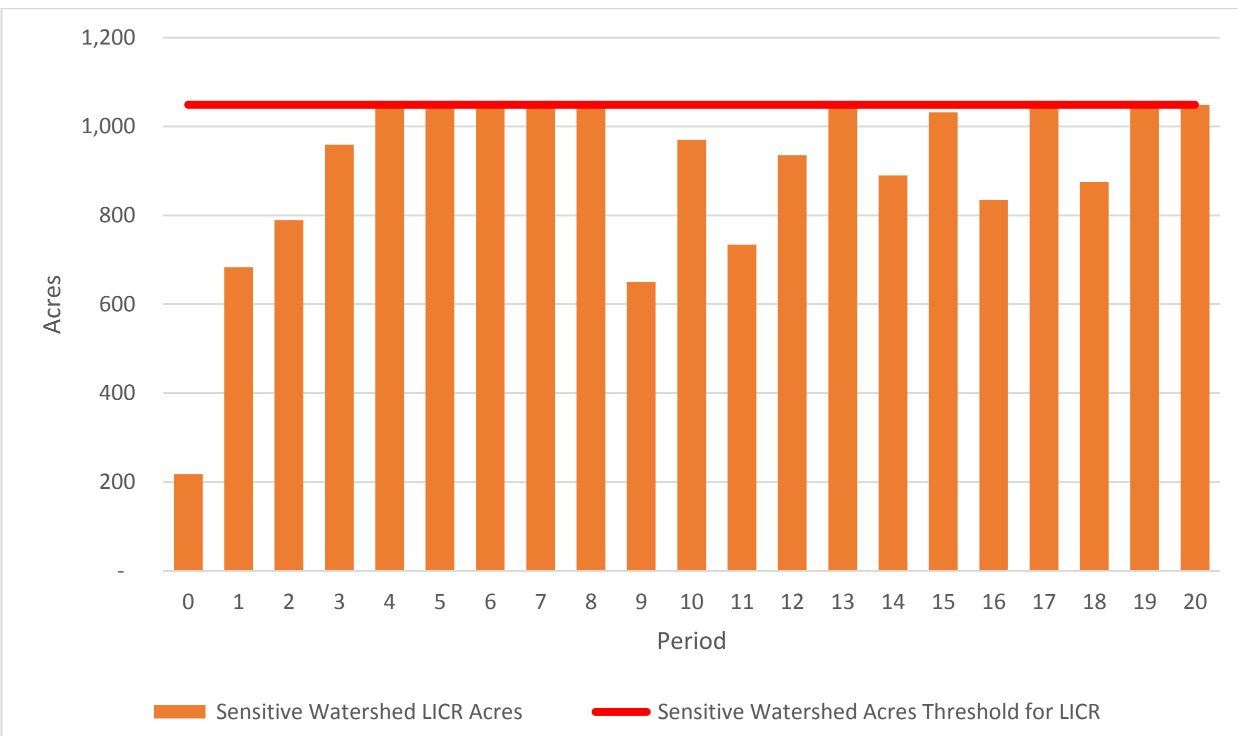


Figure 45: Sensitive Watershed Development (LICR) – Grizzly Bear Core Unconstrained

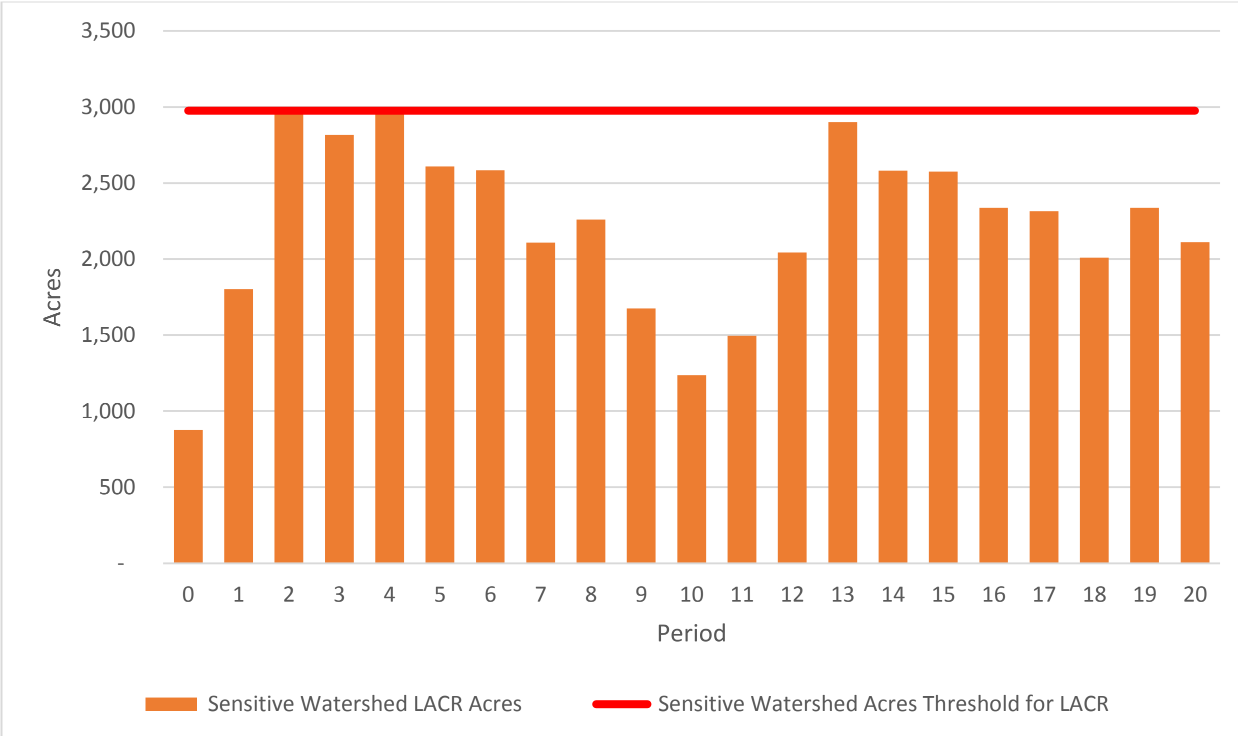


Figure 46: Sensitive Watershed Development (LACR) – Grizzly Bear Core Unconstrained

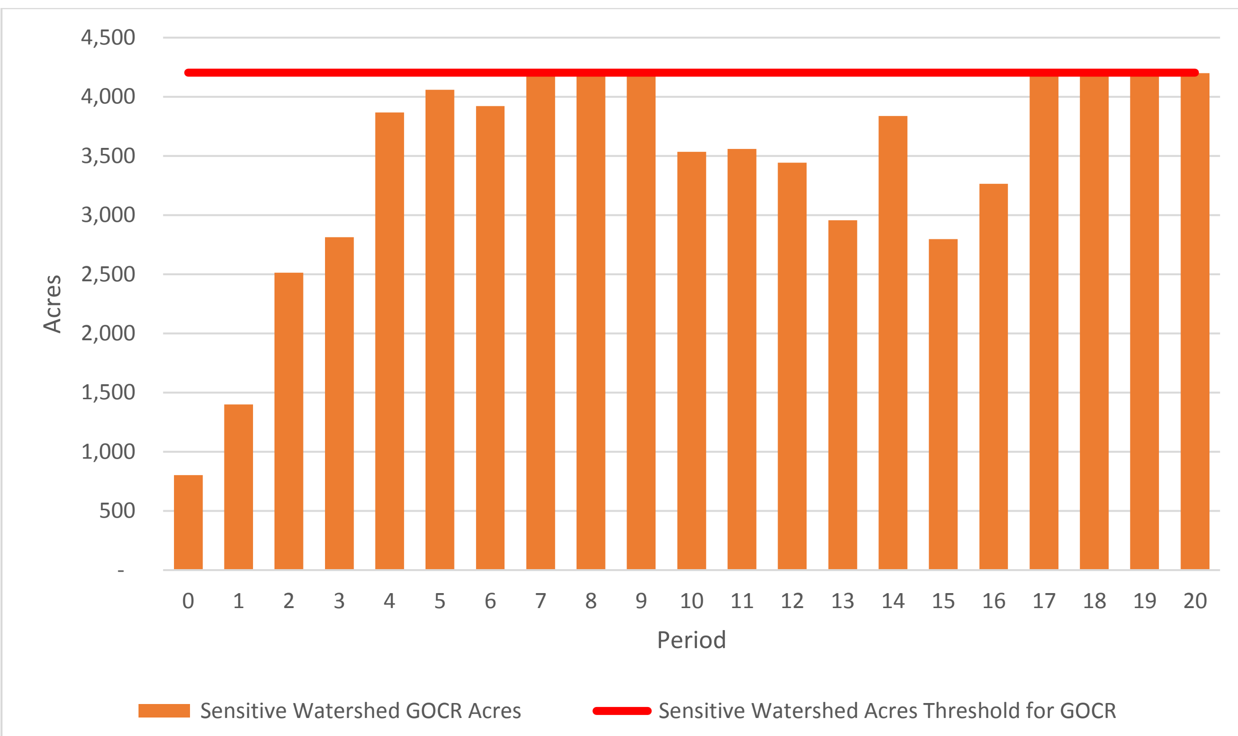


Figure 47: Sensitive Watershed Development (GOCR) – Grizzly Bear Core Unconstrained

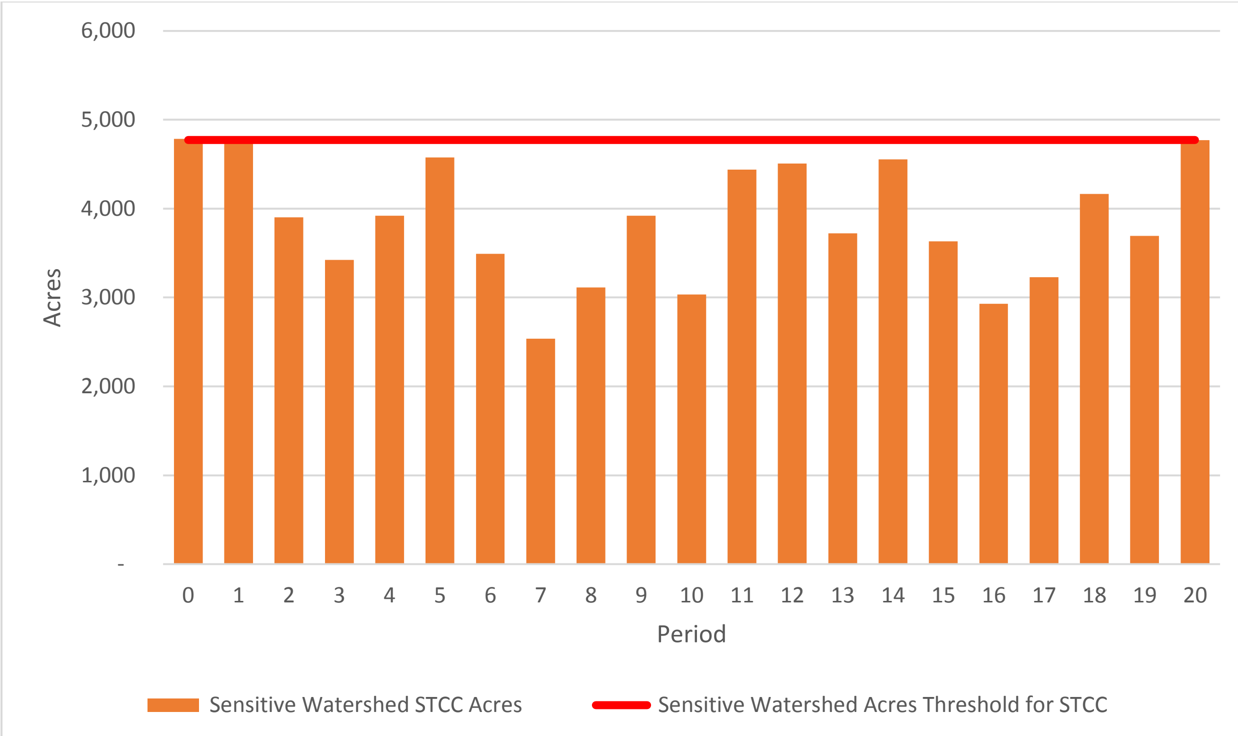


Figure 48: Sensitive Watershed Development (STCC) – Grizzly Bear Core Unconstrained

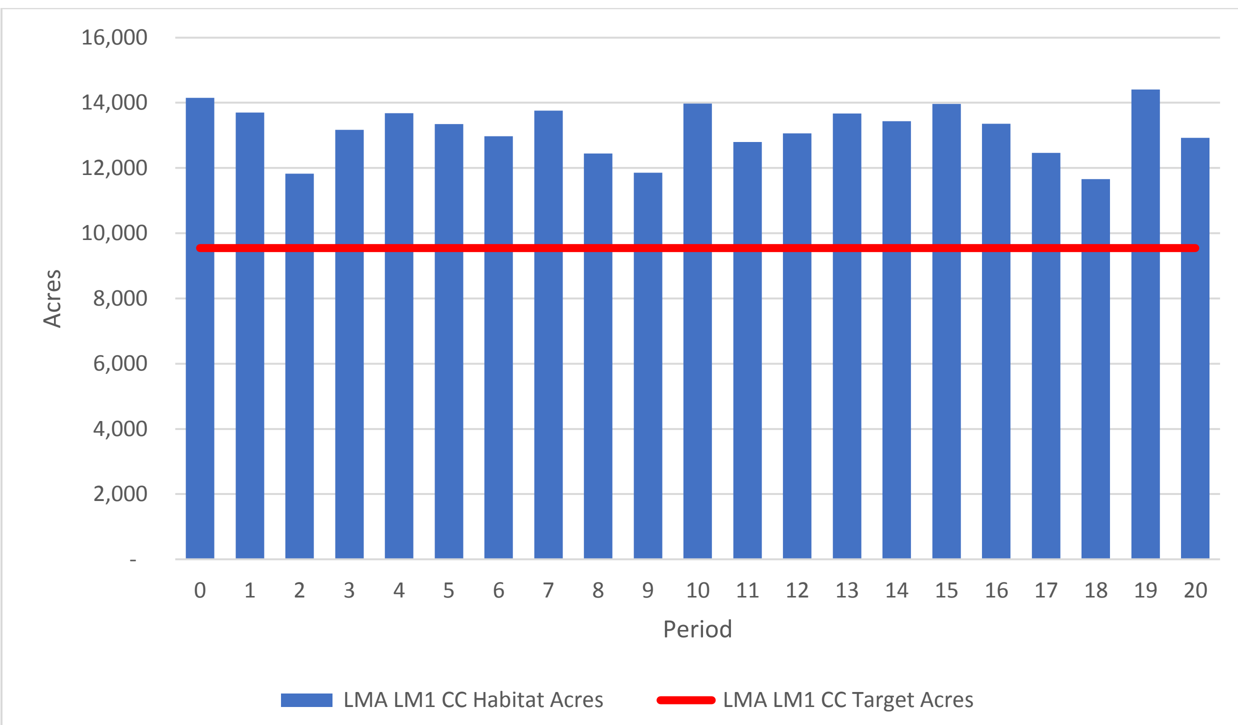


Figure 49: LMA (Coal Creek) Cover Acres – Grizzly Bear Core Unconstrained

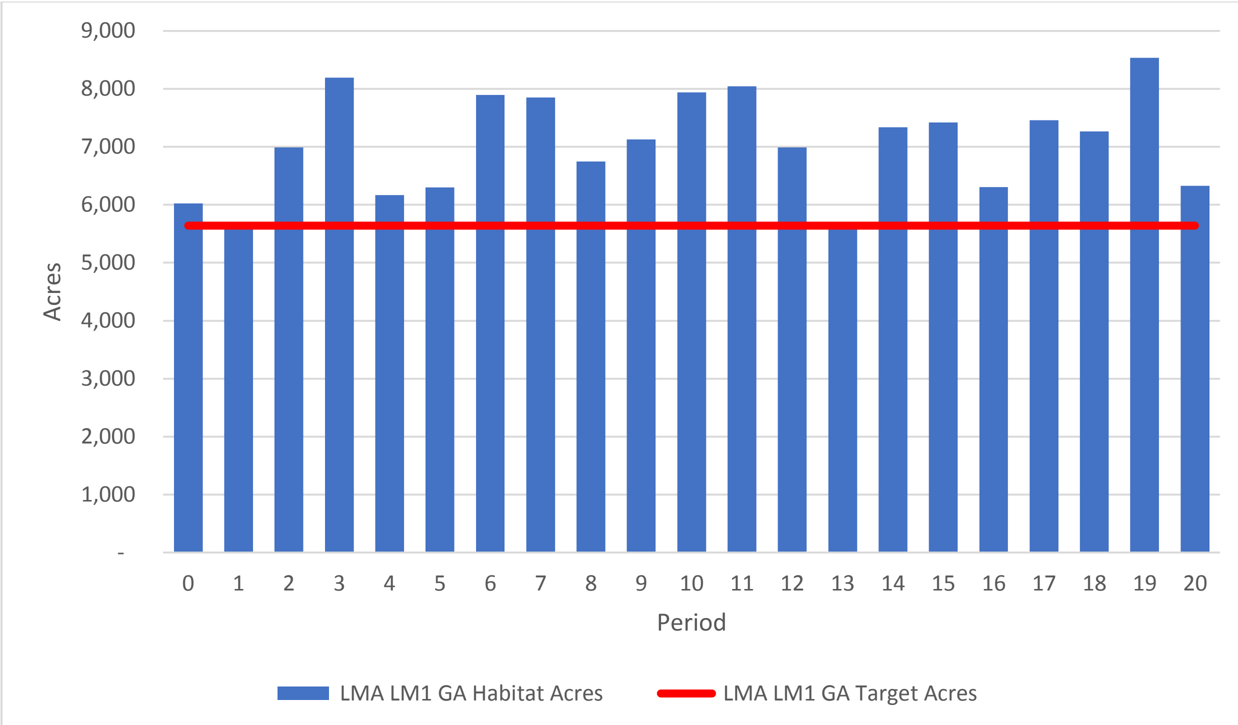


Figure 50: LMA (Garnet) Cover Acres – Grizzly Bear Core Unconstrained

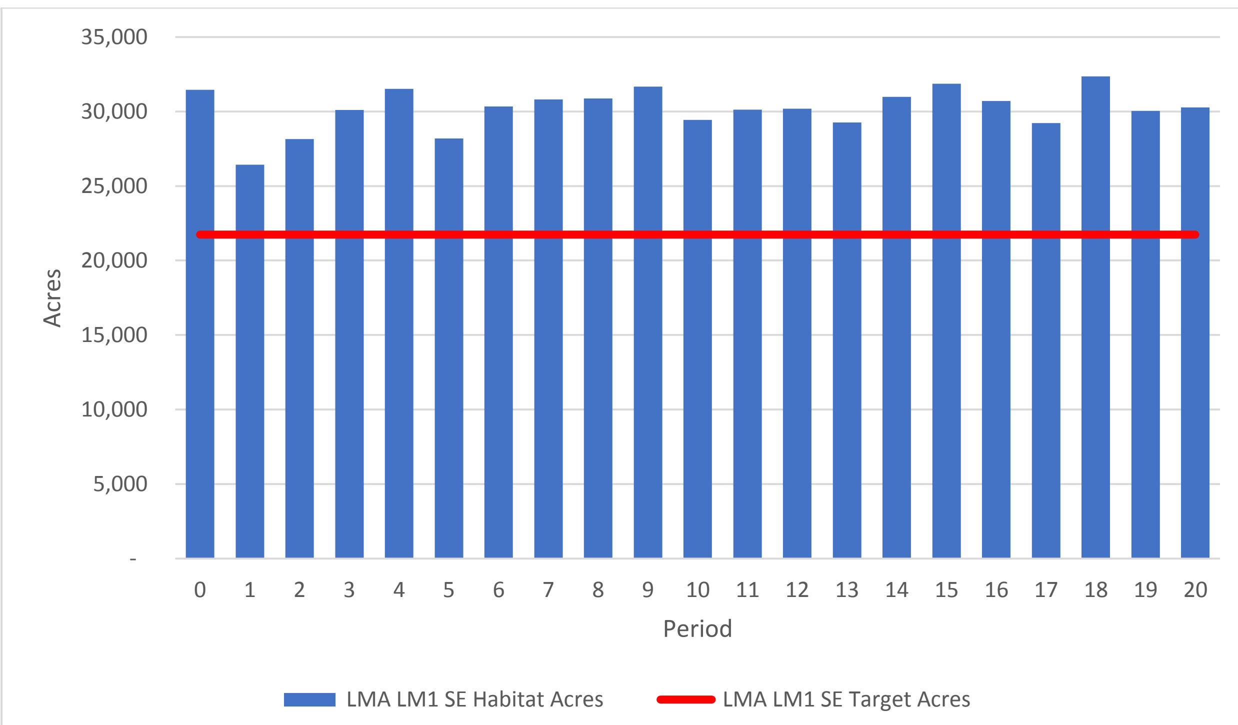


Figure 51: LMA (Stillwater East) Cover Acres – Grizzly Bear Core Unconstrained

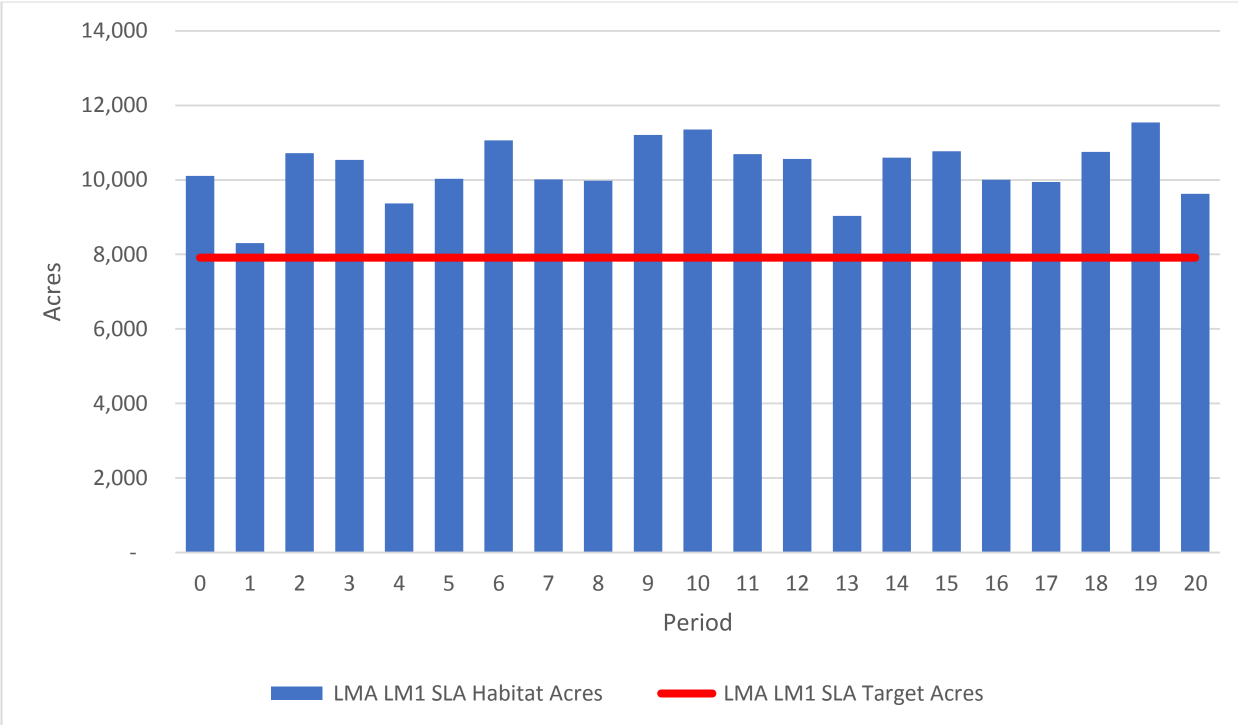


Figure 52: LMA (Seeley Lake) Cover Acres – Grizzly Bear Core Unconstrained

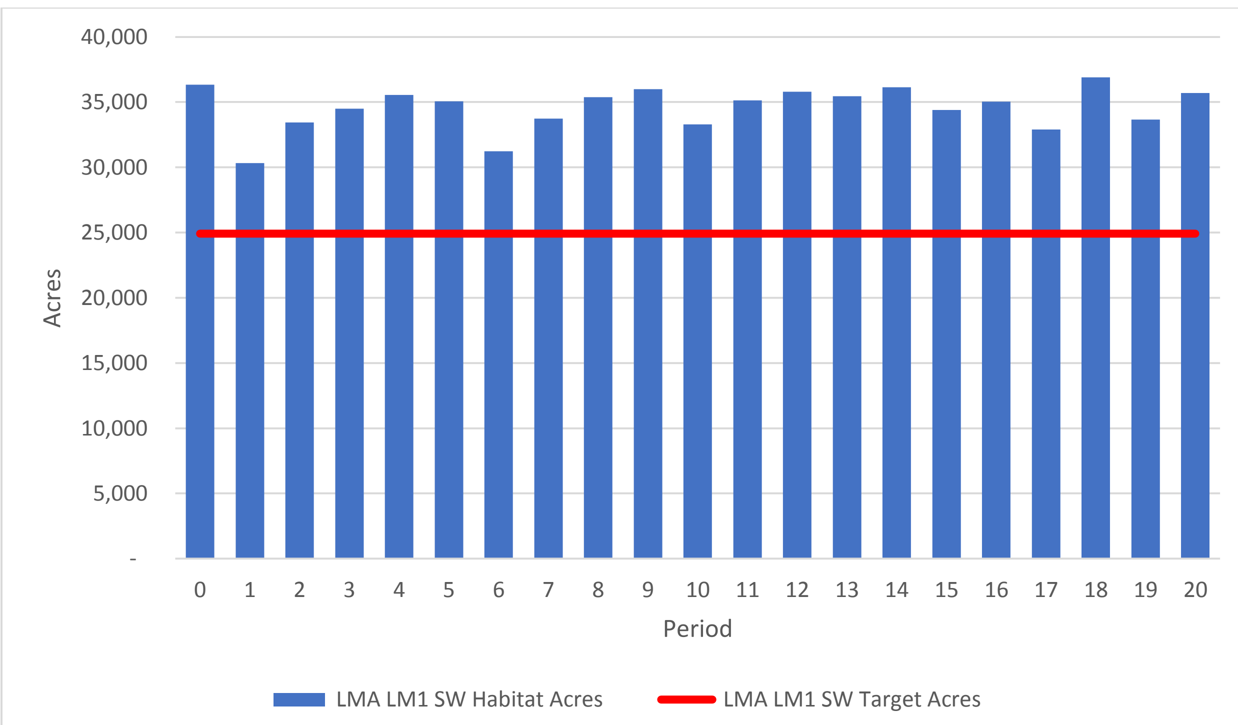


Figure 53: LMA (Stillwater West) Cover Acres – Grizzly Bear Core Unconstrained

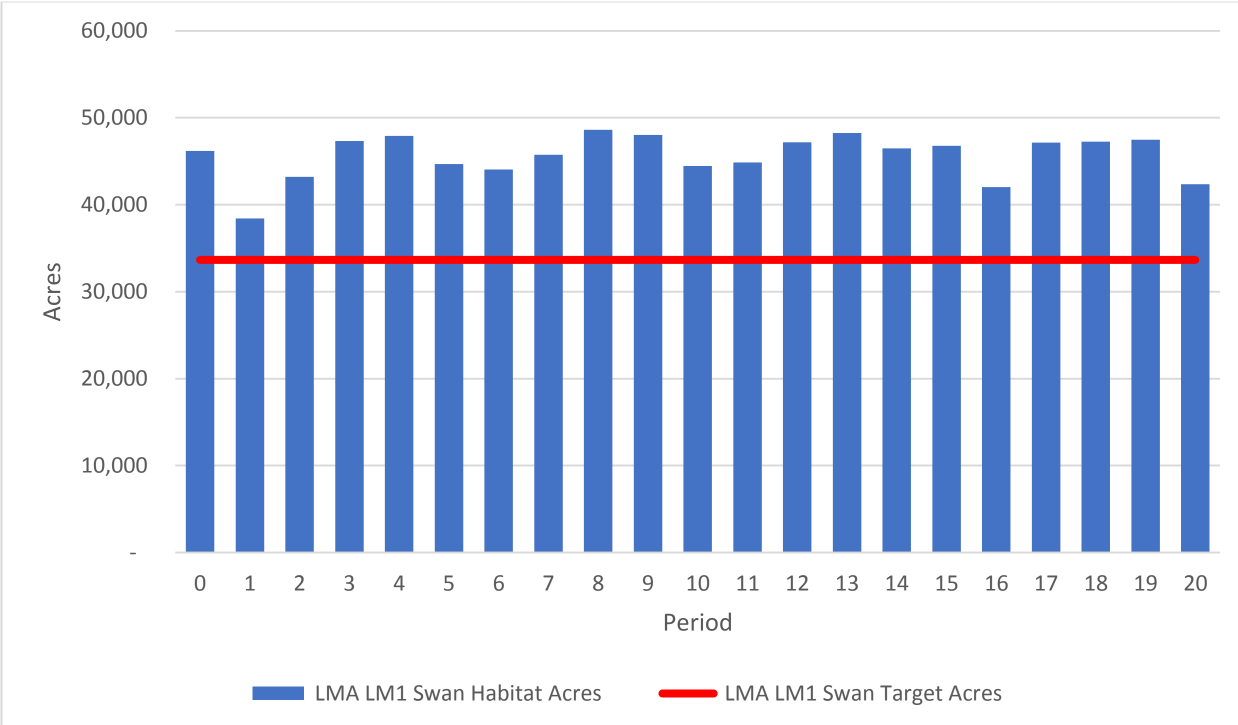


Figure 54: LMA (Swan) Cover Acres – Grizzly Bear Core Unconstrained

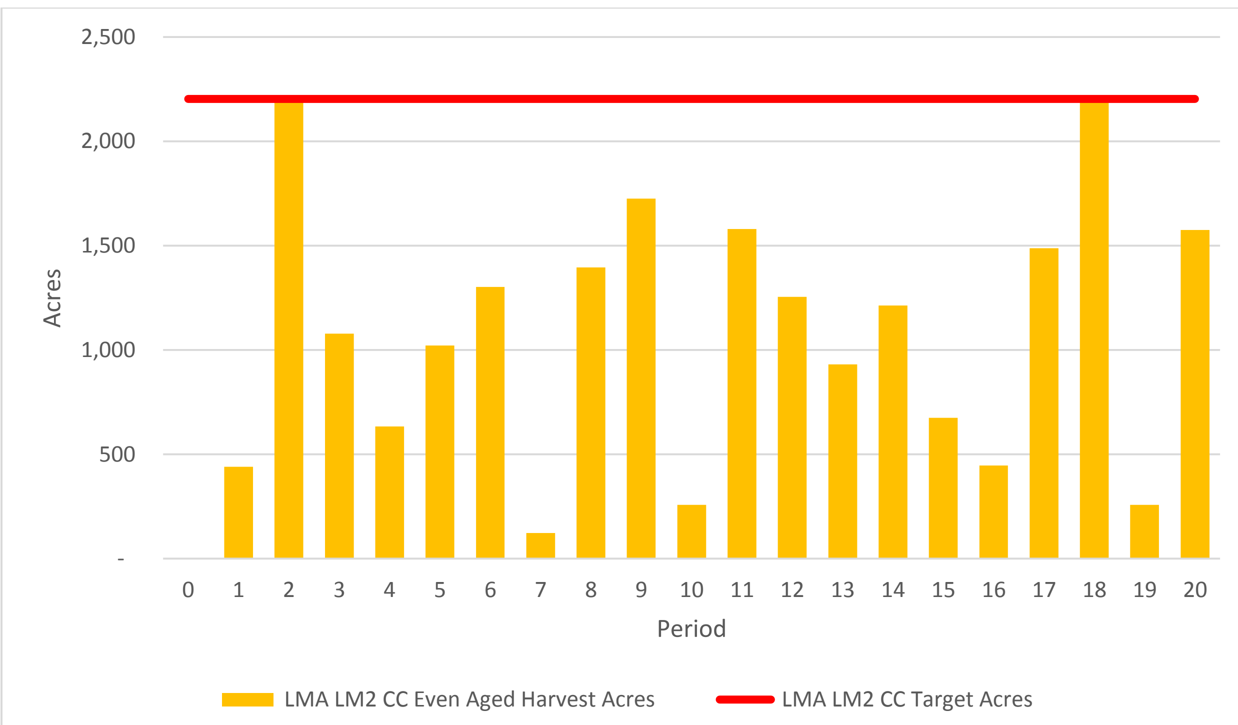


Figure 55: LMA (Coal Creek) EA Harvest Acres – Grizzly Bear Core Unconstrained

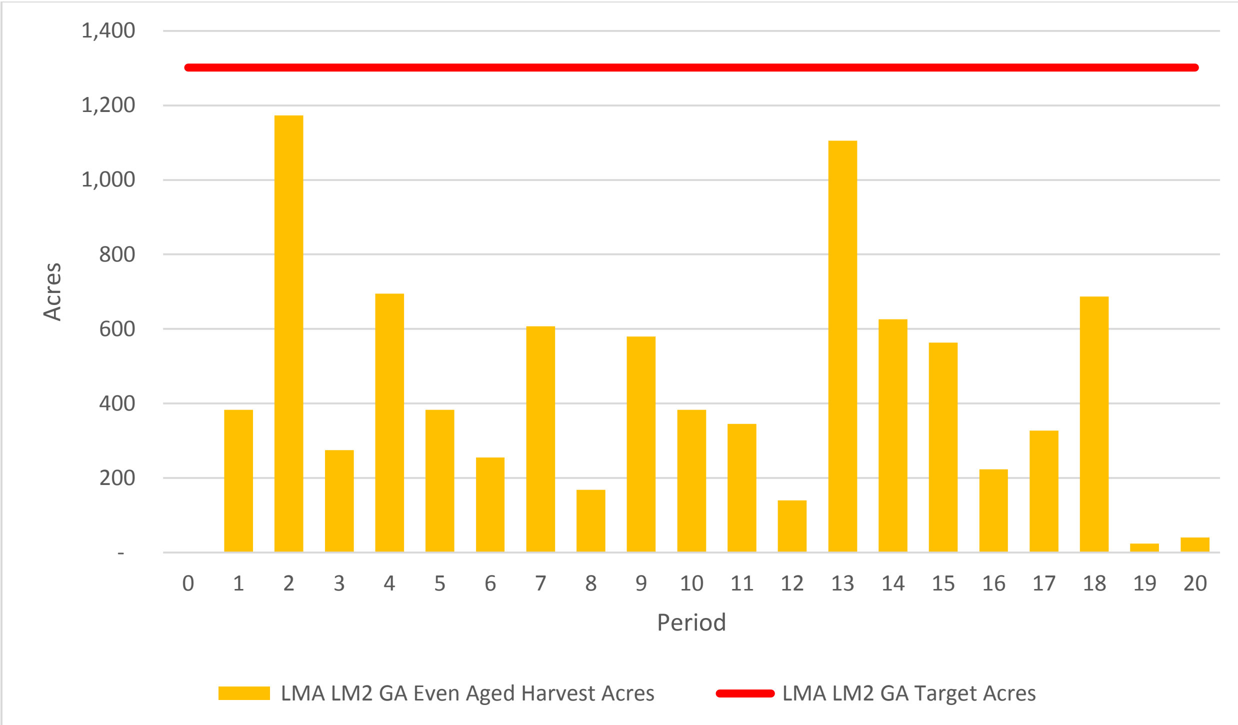


Figure 56: LMA (Garnet) EA Harvest Acres – Grizzly Bear Core Unconstrained

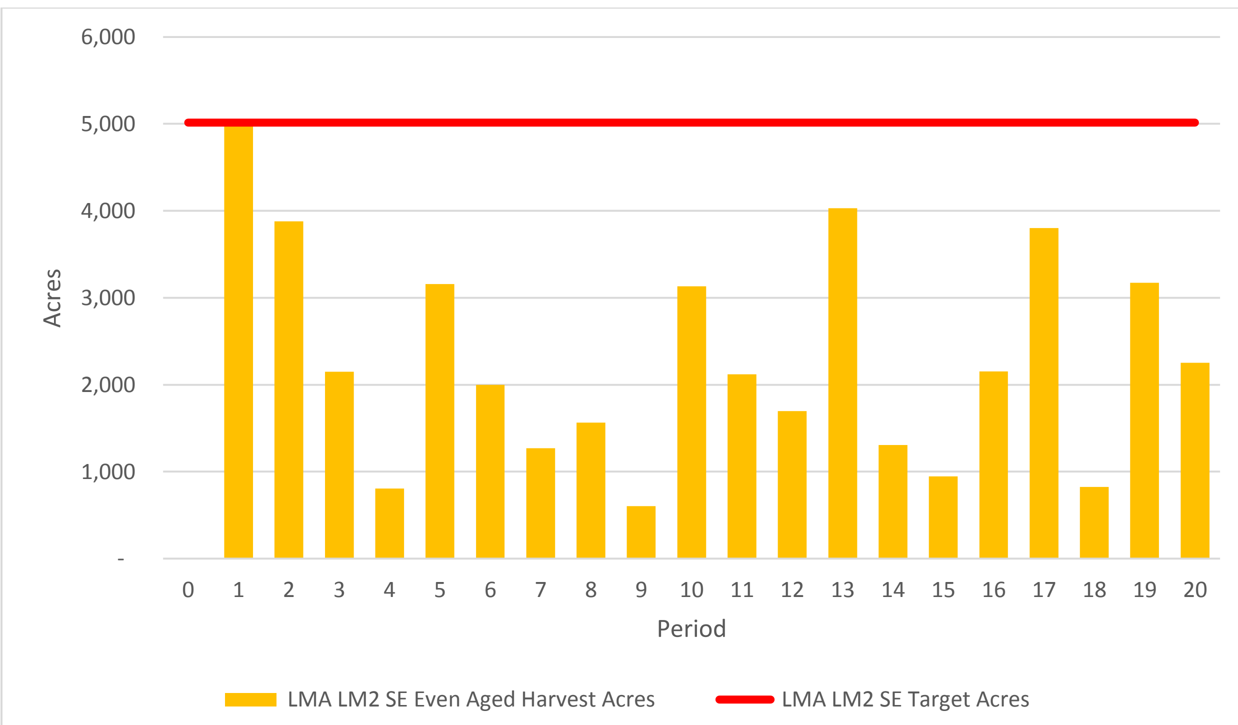


Figure 57: LMA (Stillwater East) EA Harvest Acres – Grizzly Bear Core Unconstrained

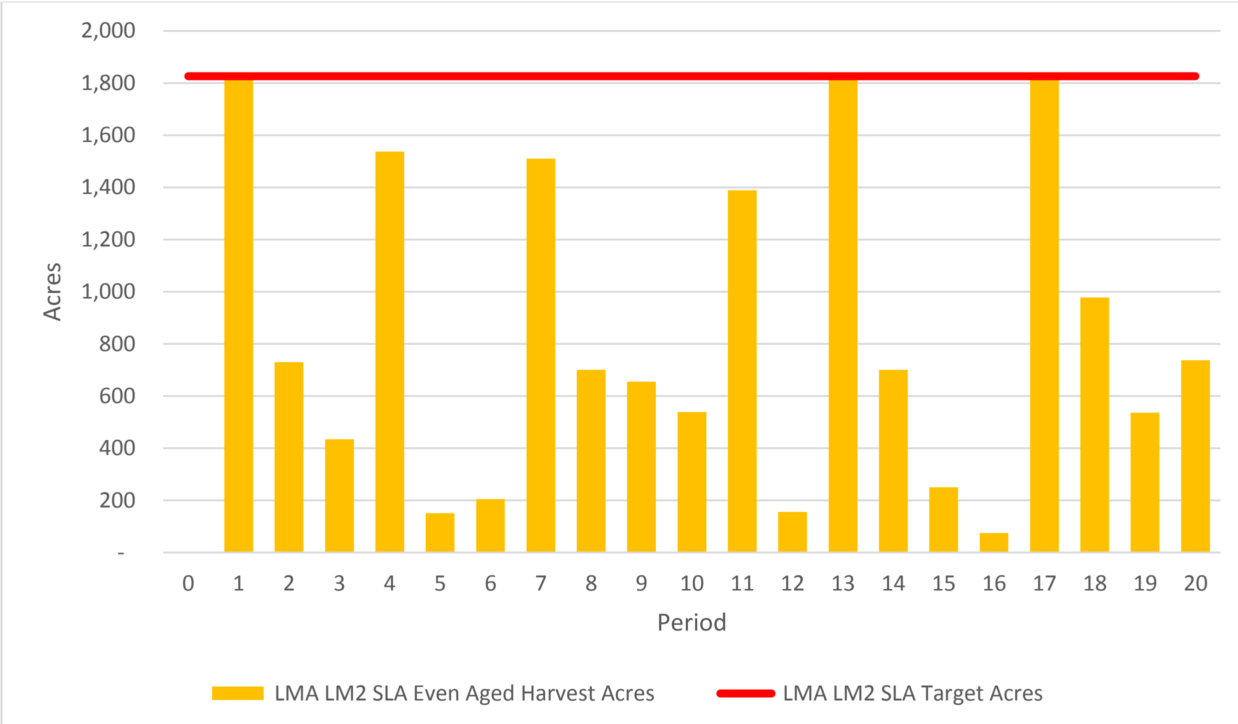


Figure 58: LMA (Seeley Lake) EA Harvest Acres – Grizzly Bear Core Unconstrained

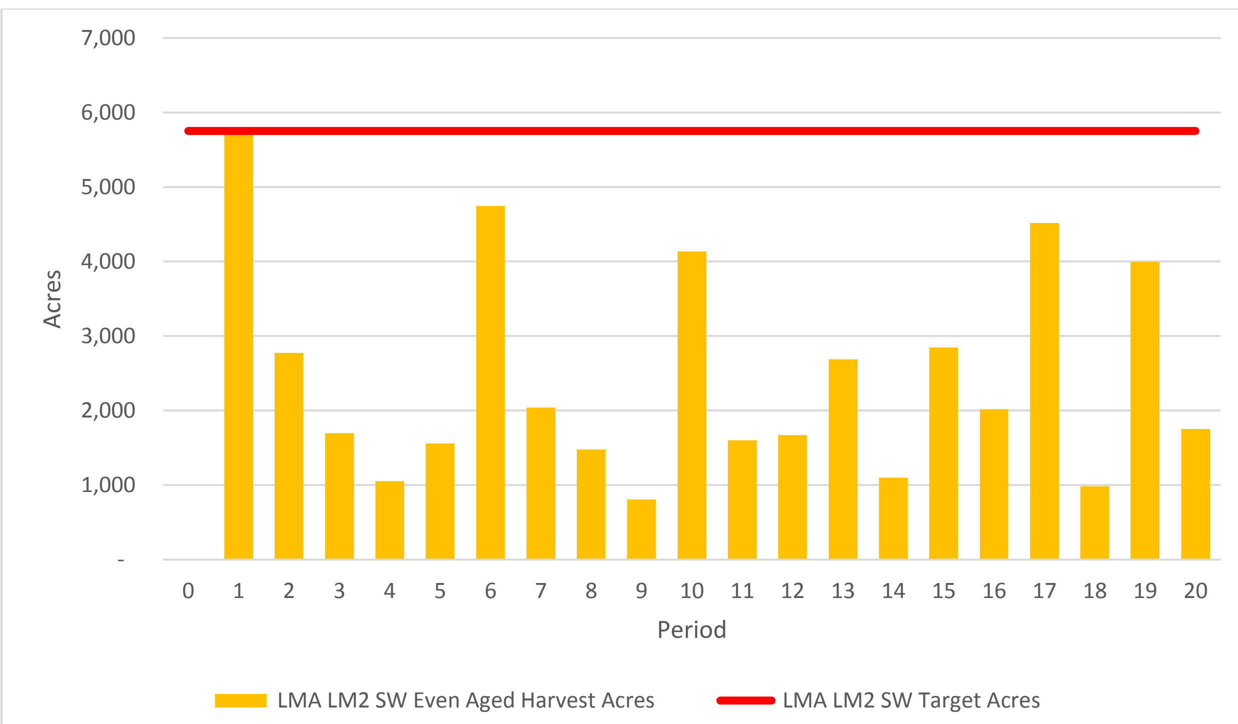


Figure 59: LMA (Stillwater West) EA Harvest Acres – Grizzly Bear Core Unconstrained

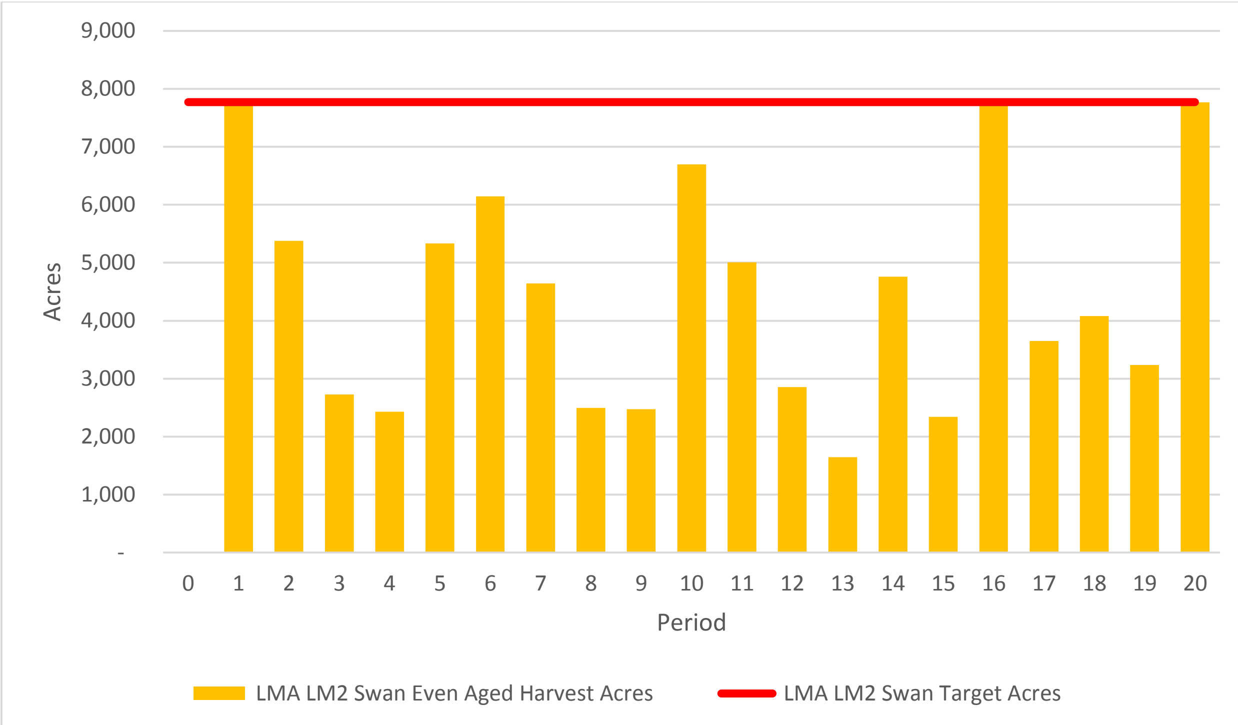


Figure 60: LMA (Swan) EA Harvest Acres – Grizzly Bear Core Unconstrained

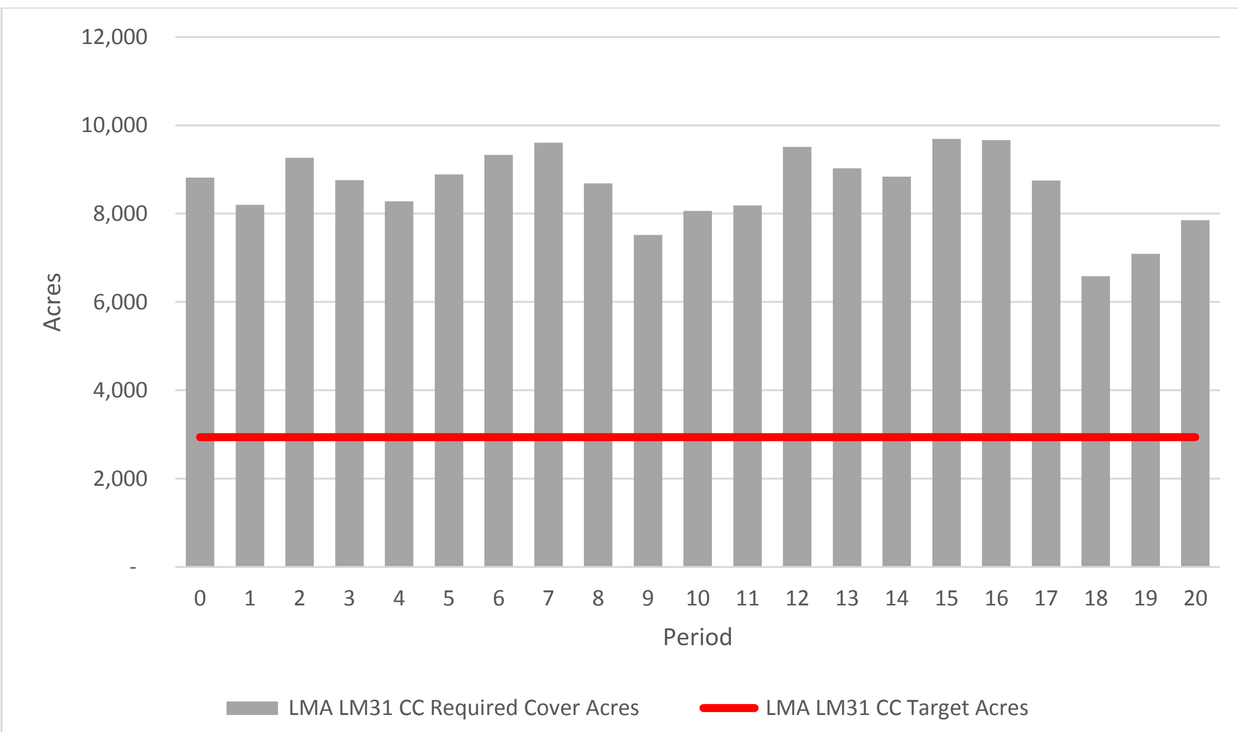


Figure 61: LMA (Coal Creek) Saw-Timber Acres – Grizzly Bear Core Unconstrained

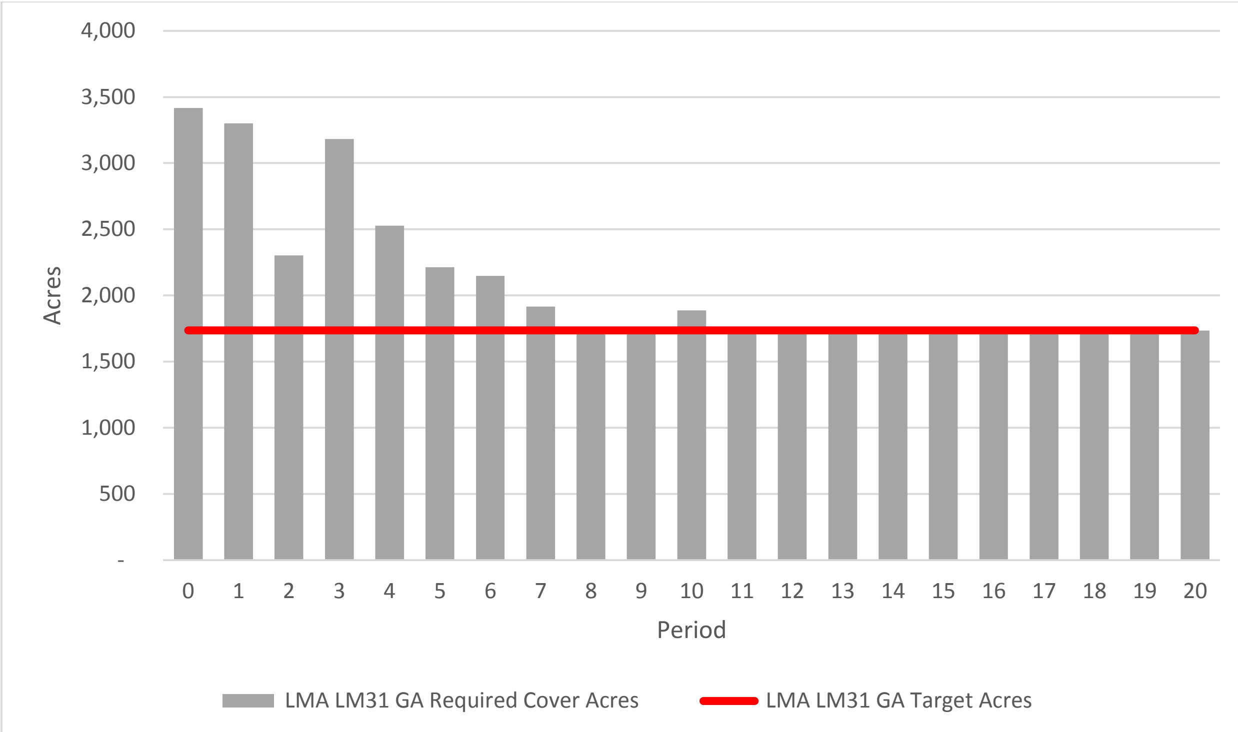


Figure 62: LMA (Garnet) Saw-Timber Acres – Grizzly Bear Core Unconstrained

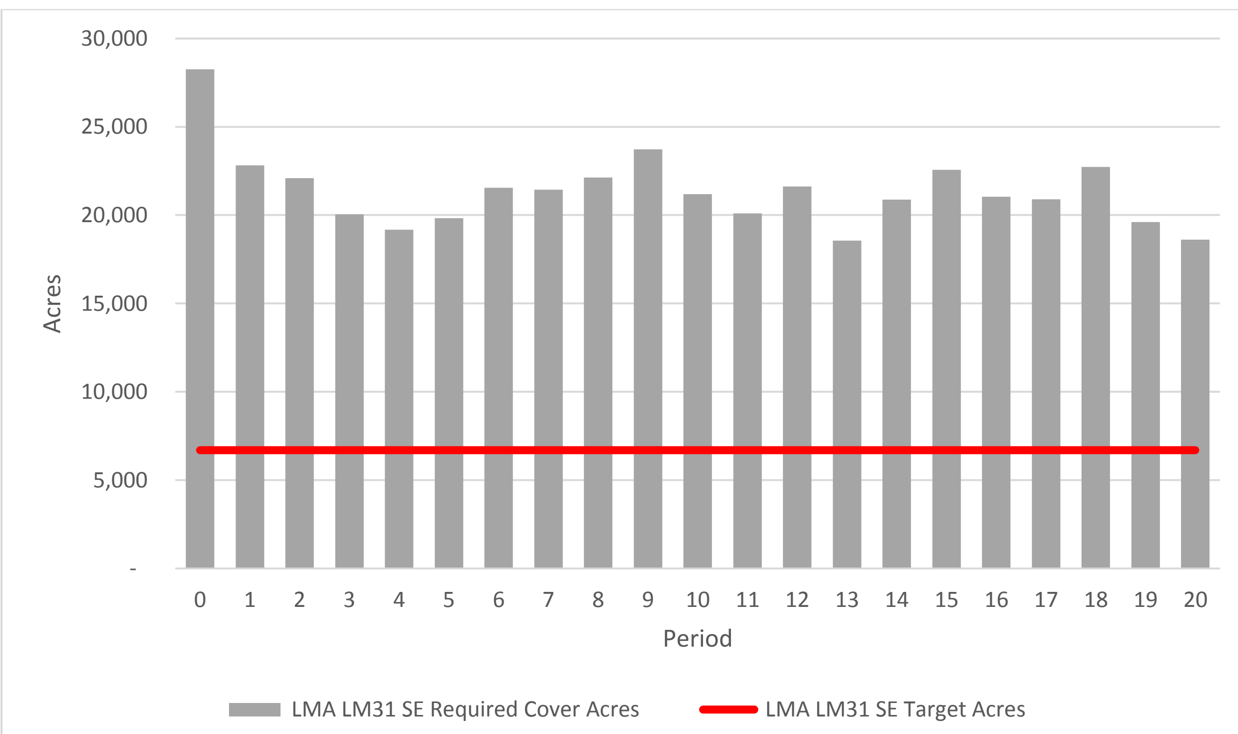


Figure 63: LMA (Stillwater East) Saw-Timber Acres – Grizzly Bear Core Unconstrained

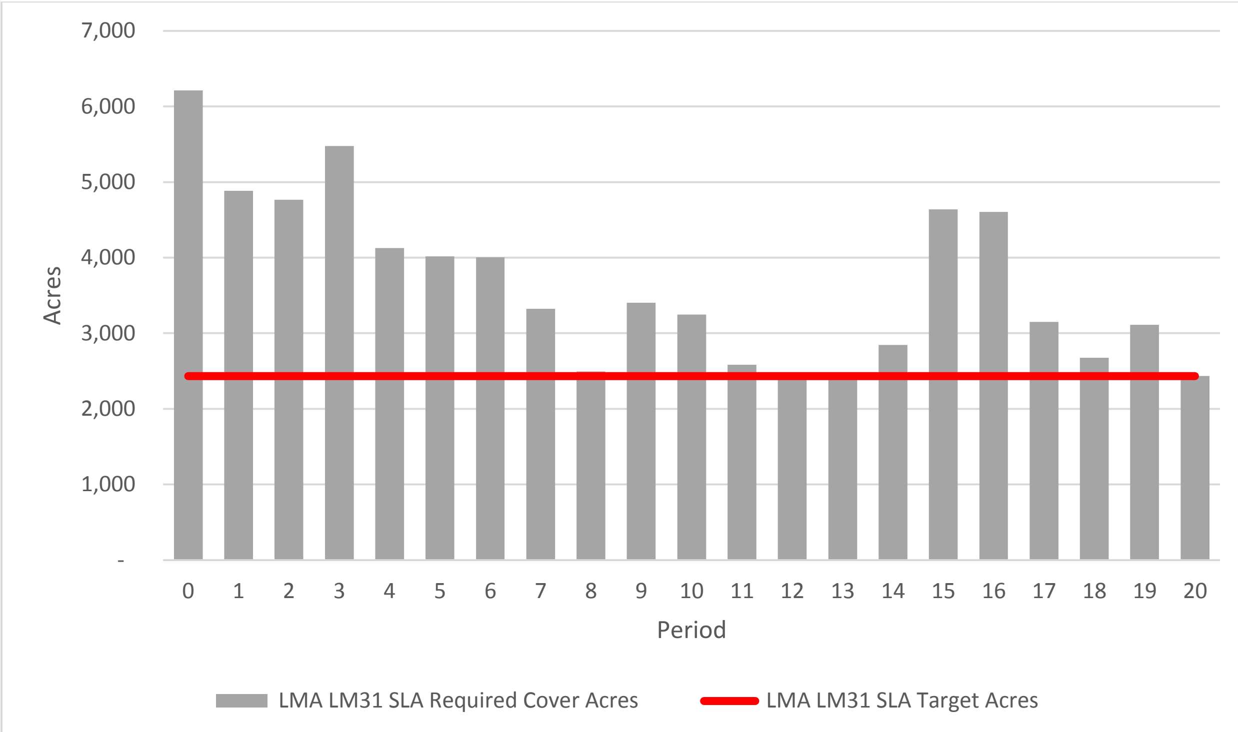


Figure 64: LMA (Seeley Lake) Saw-Timber Acres – Grizzly Bear Core Unconstrained

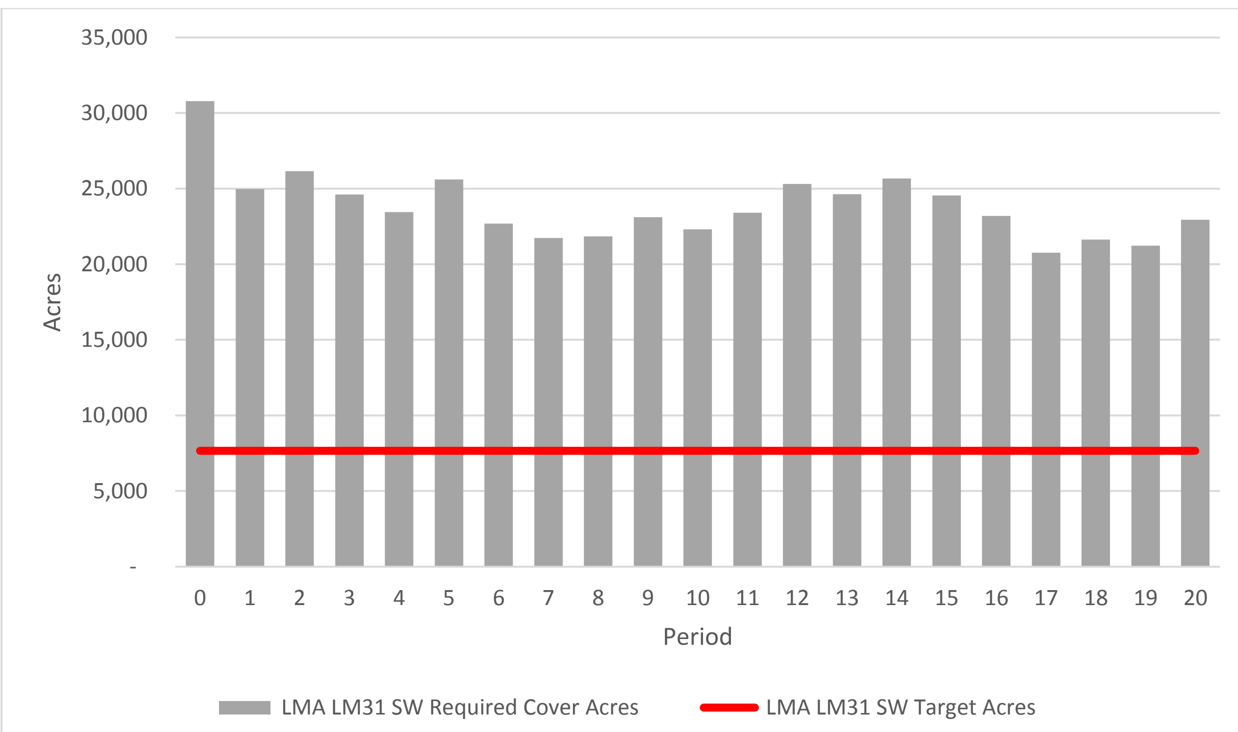


Figure 65: LMA (Stillwater West) Saw-Timber Acres – Grizzly Bear Core Unconstrained

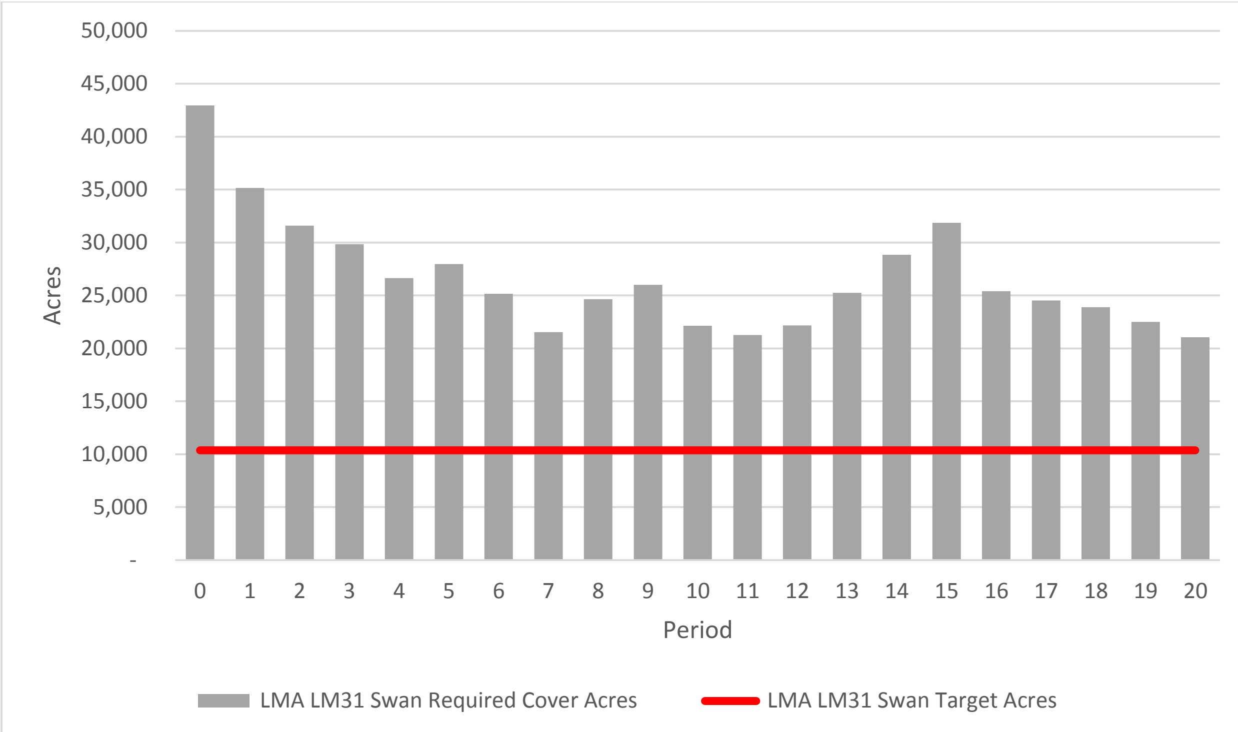


Figure 66: LMA (Swan) Saw-Timber Acres – Grizzly Bear Core Unconstrained

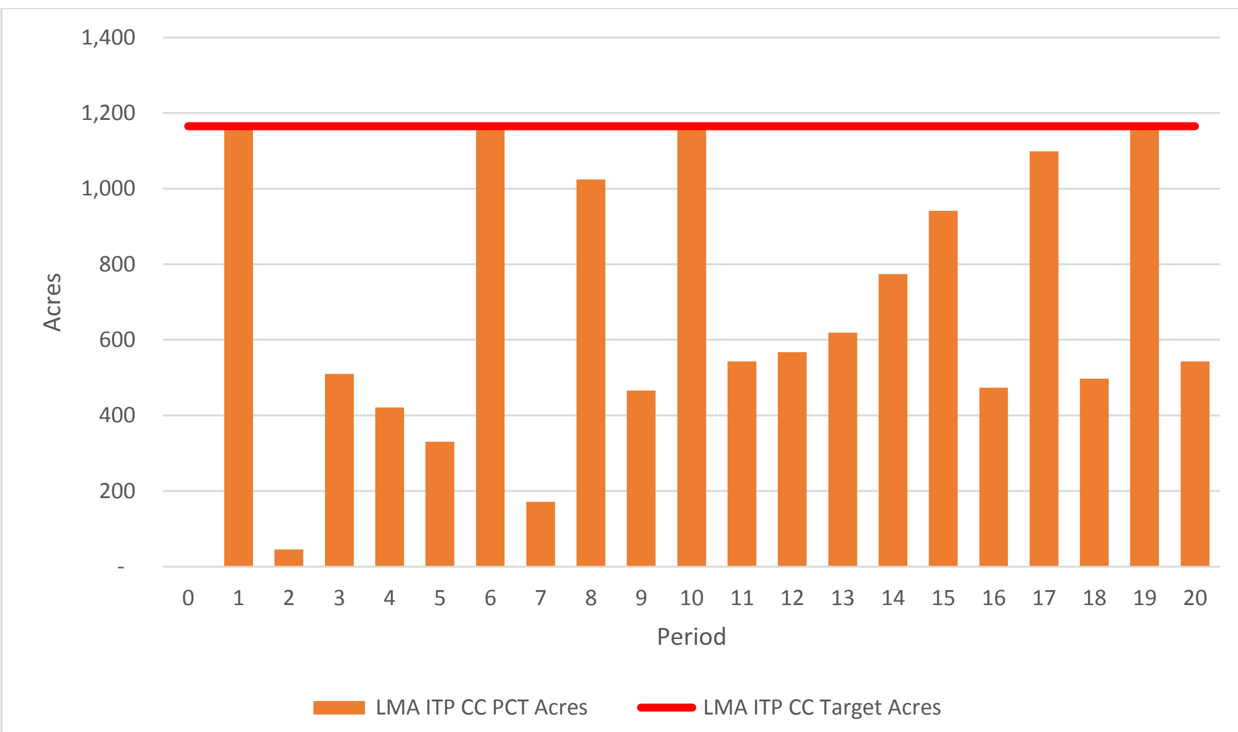


Figure 67: LMA (Coal Creek) PCT Acres – Grizzly Bear Core Unconstrained

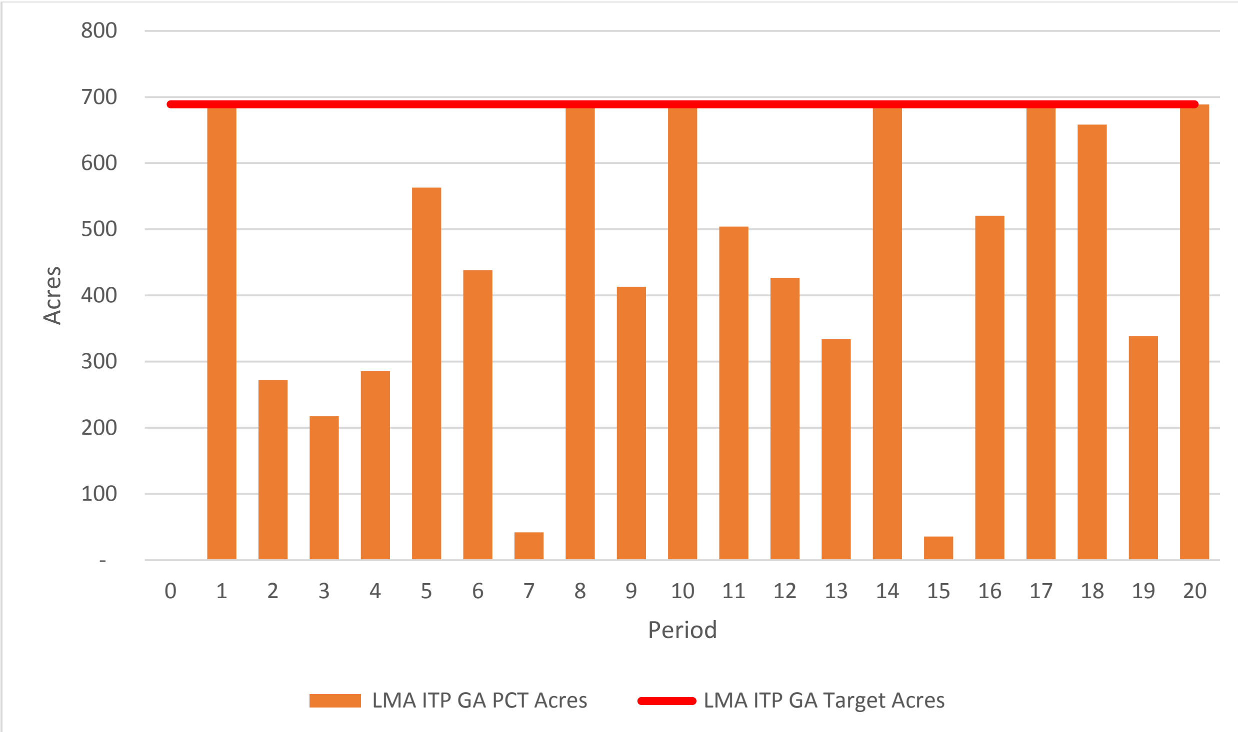


Figure 68: LMA (Garnet) PCT Acres – Grizzly Bear Core Unconstrained

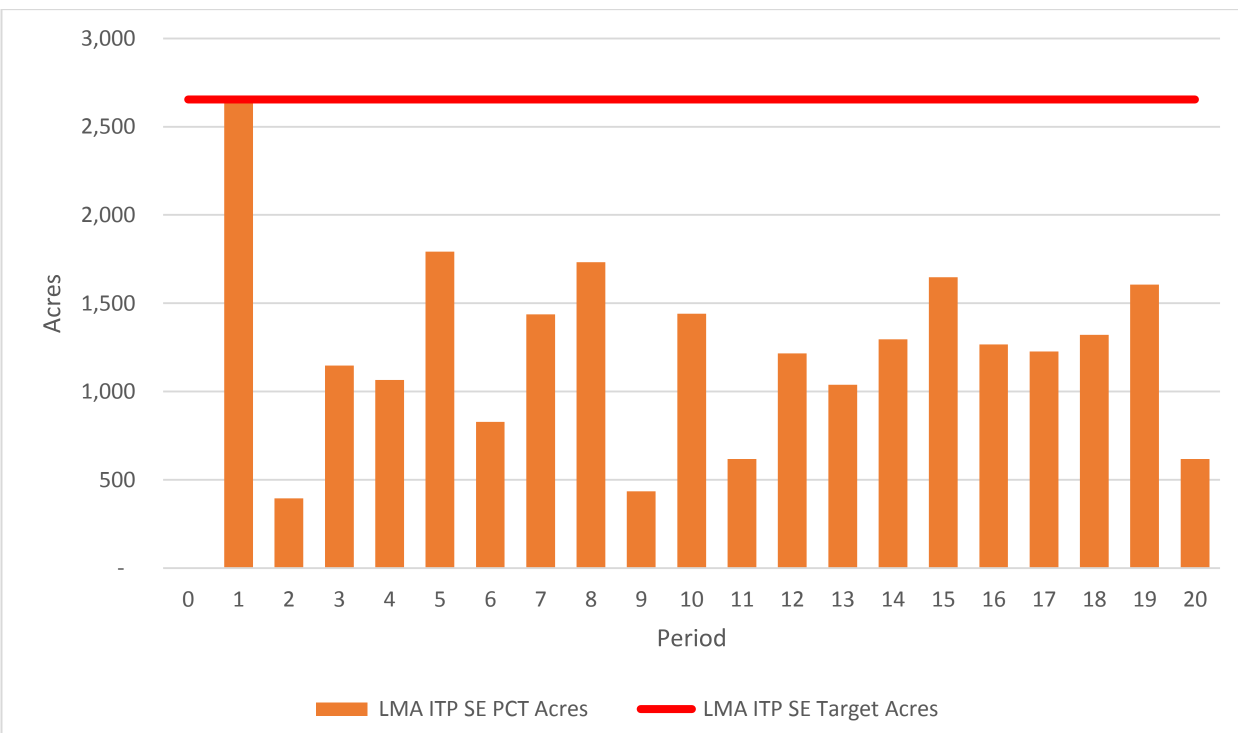


Figure 69: LMA (Stillwater East) PCT Acres – Grizzly Bear Core Unconstrained

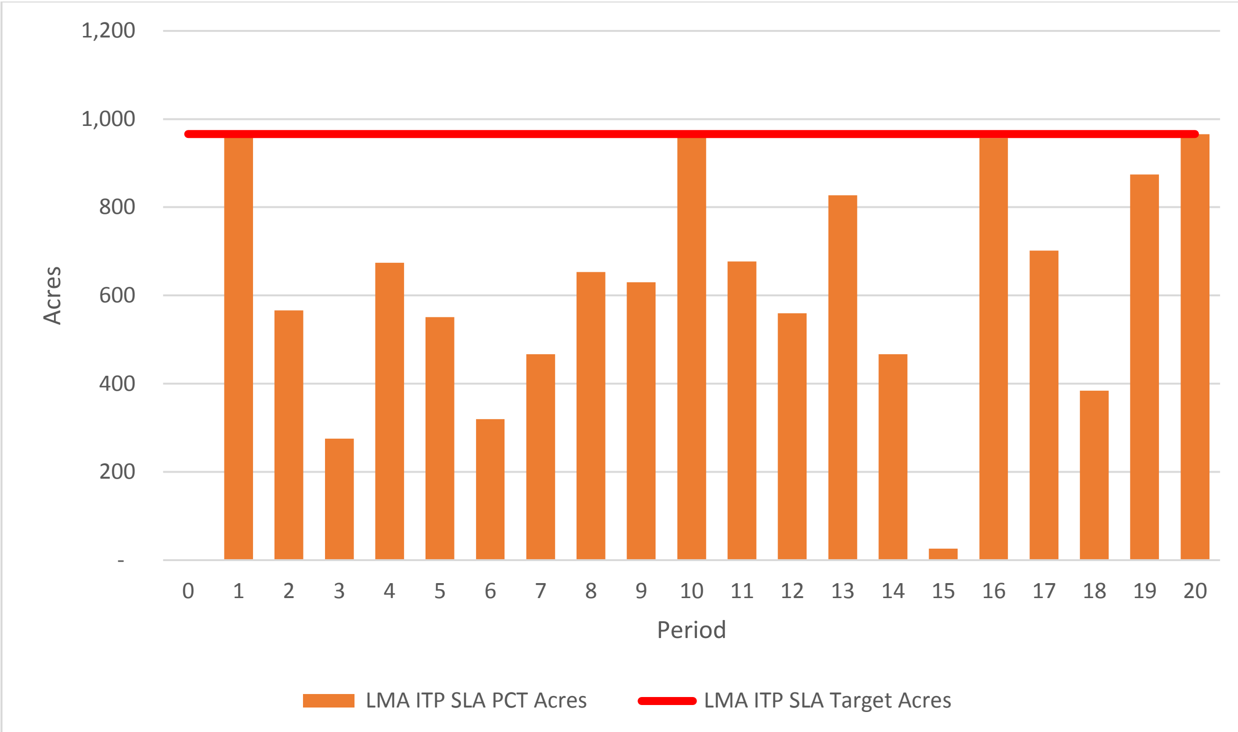


Figure 70: LMA (Seeley Lake) PCT Acres – Grizzly Bear Core Unconstrained

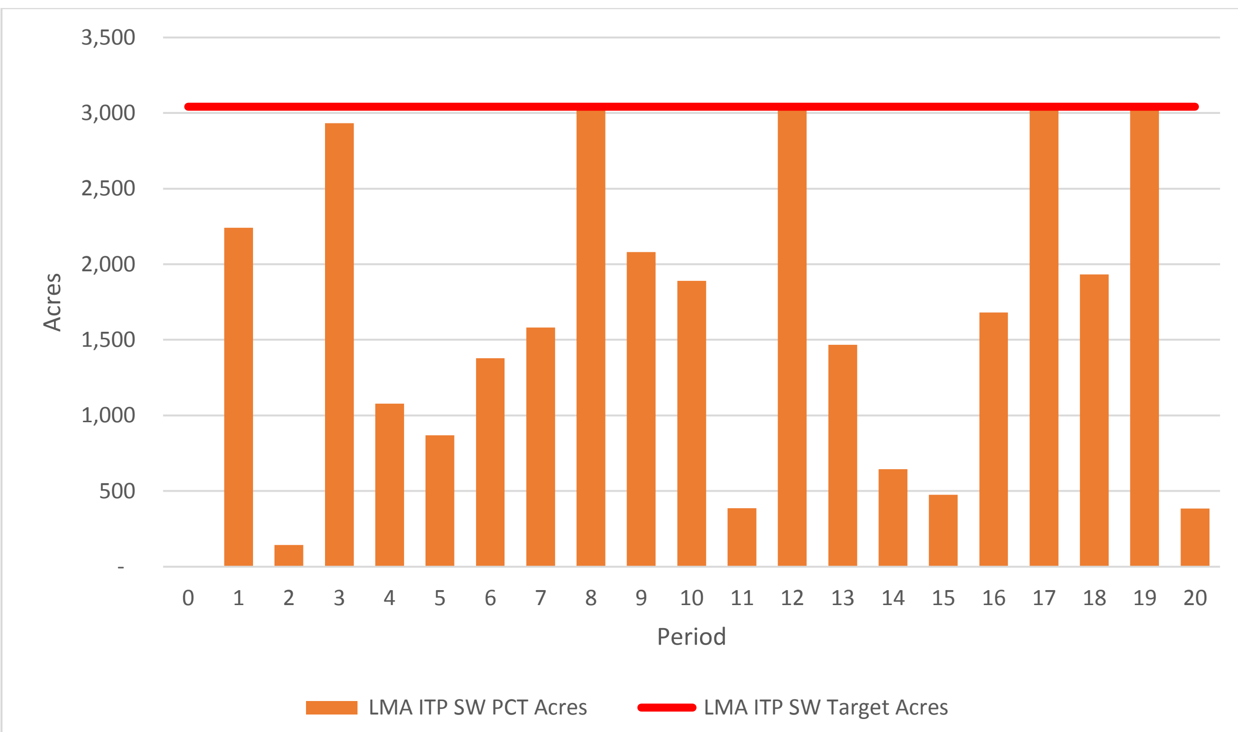


Figure 71: LMA (Stillwater West) PCT Acres – Grizzly Bear Core Unconstrained

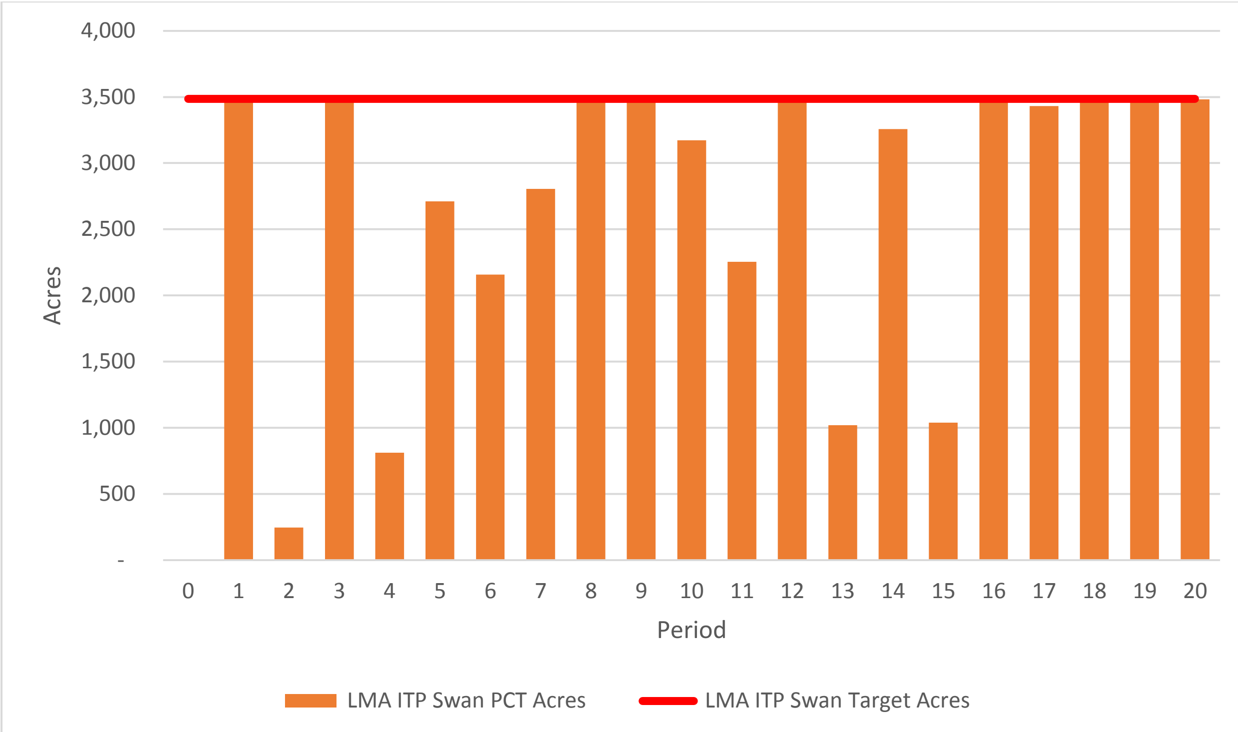


Figure 72: LMA (Swan) PCT Acres – Grizzly Bear Core Unconstrained

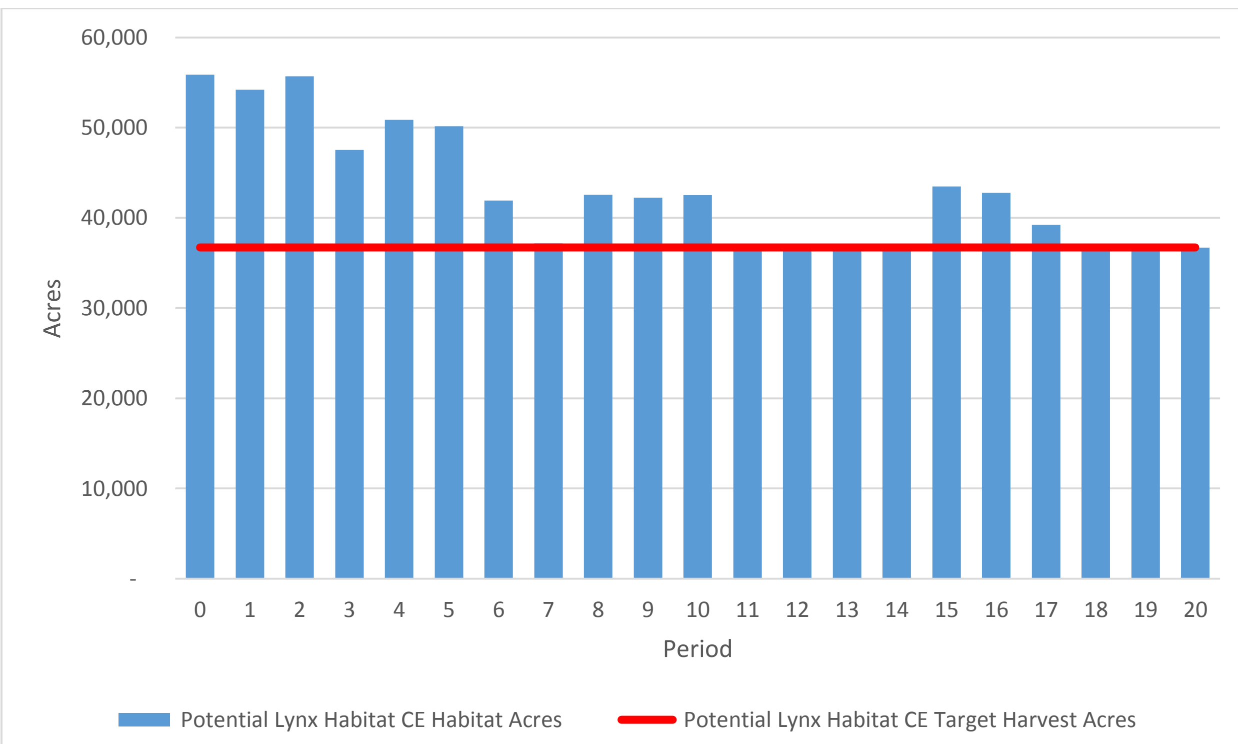


Figure 73: Potential Lynx Habitat Development (CE) – Grizzly Bear Core Unconstrained

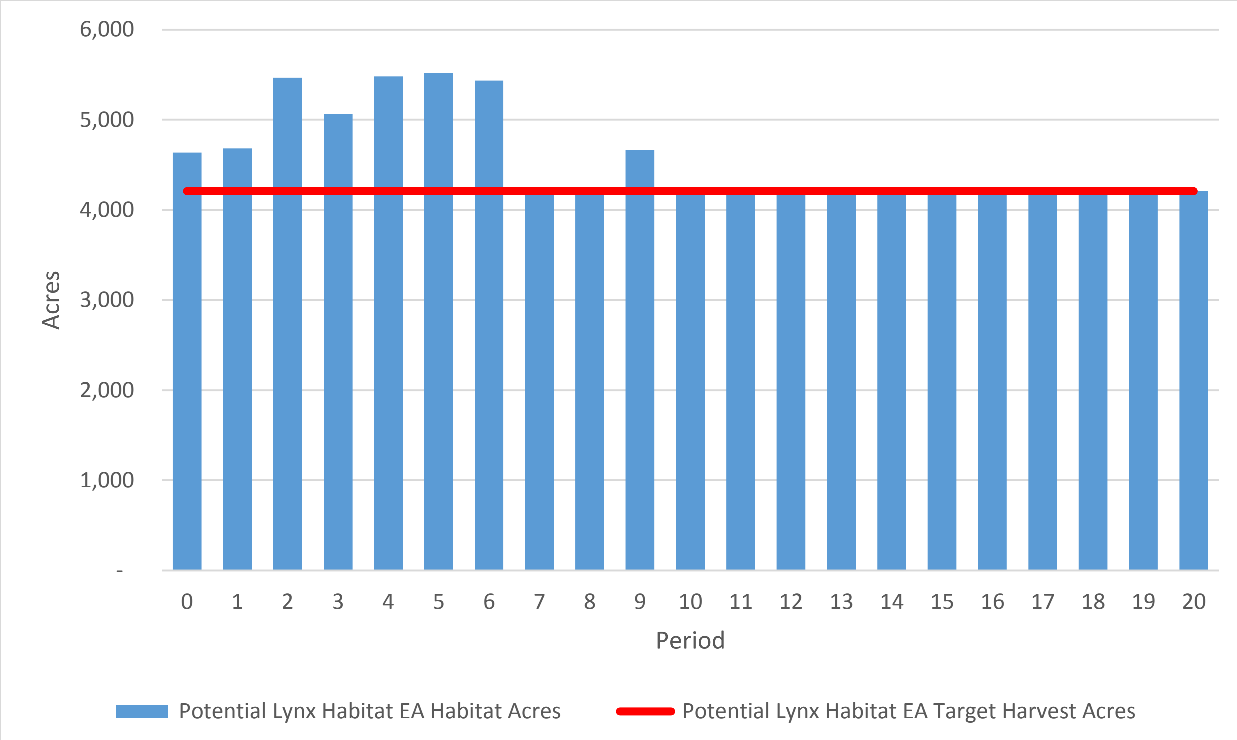


Figure 74: Potential Lynx Habitat Development (EA) – Grizzly Bear Core Unconstrained

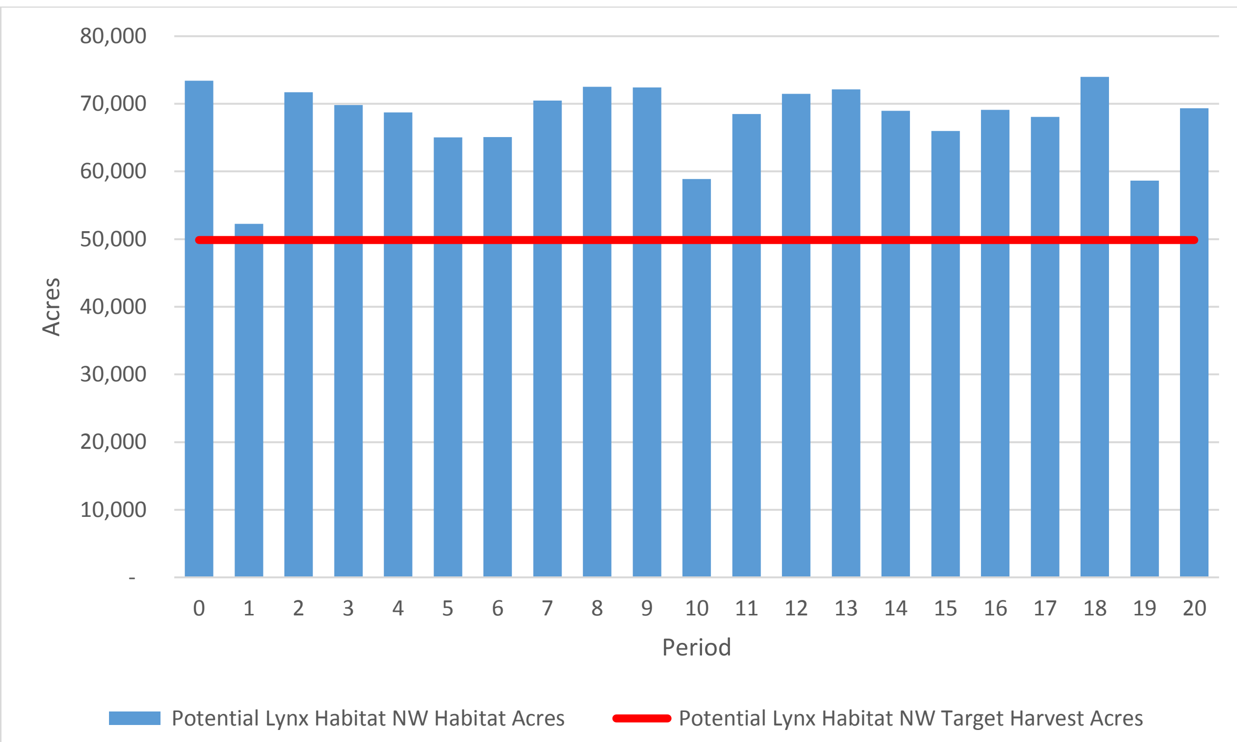


Figure 75: Potential Lynx Habitat Development (NW) – Grizzly Bear Core Unconstrained

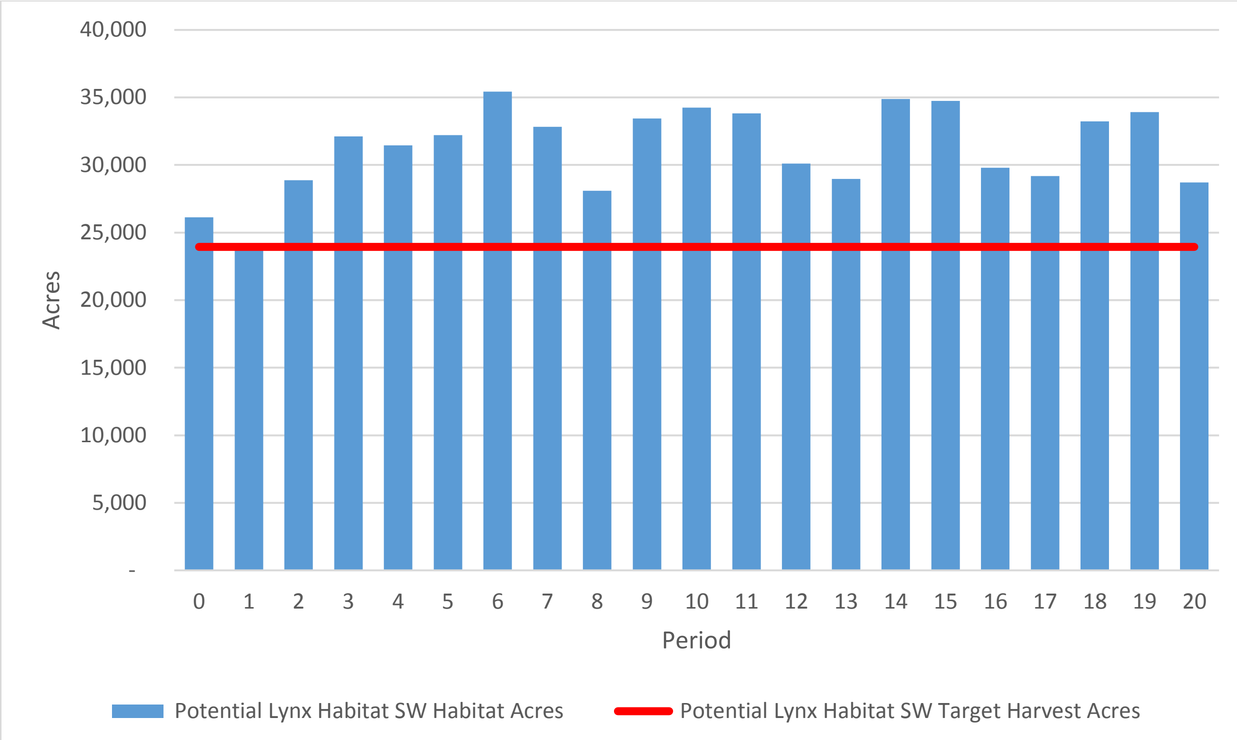


Figure 76: Potential Lynx Habitat Development (SW) – Grizzly Bear Core Unconstrained

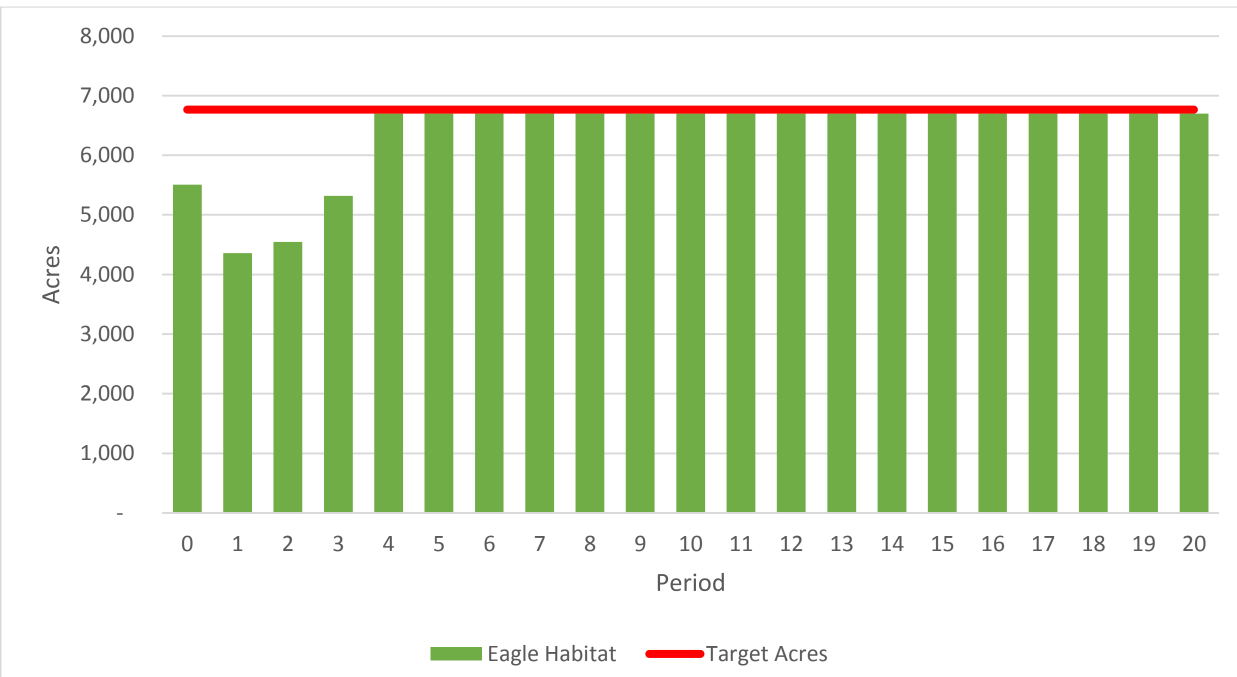


Figure 77: Bald Eagle Habitat Acres – Grizzly Bear Core Unconstrained

Figure 78: CE Old Growth Acres (Bozeman) – Grizzly Bear Core Unconstrained

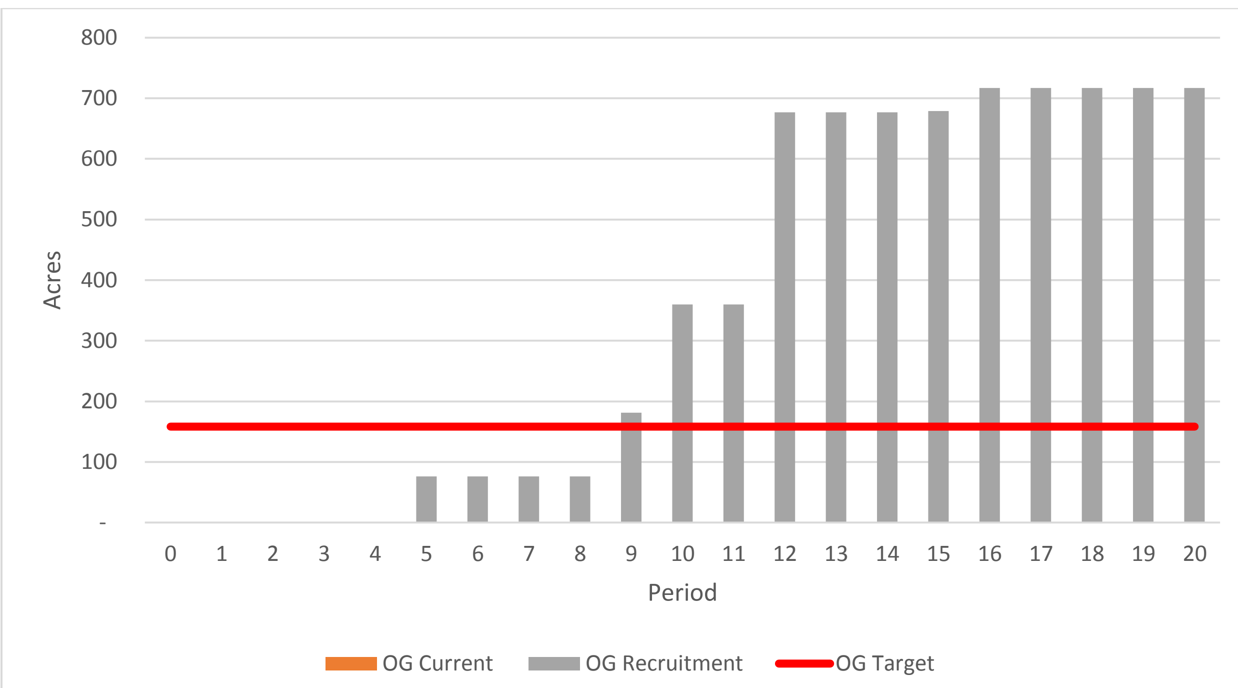


Figure 79: CE Old Growth Acres (Conrad) – Grizzly Bear Core Unconstrained

Figure 80: CE Old Growth Acres (Dillon) – Grizzly Bear Core Unconstrained

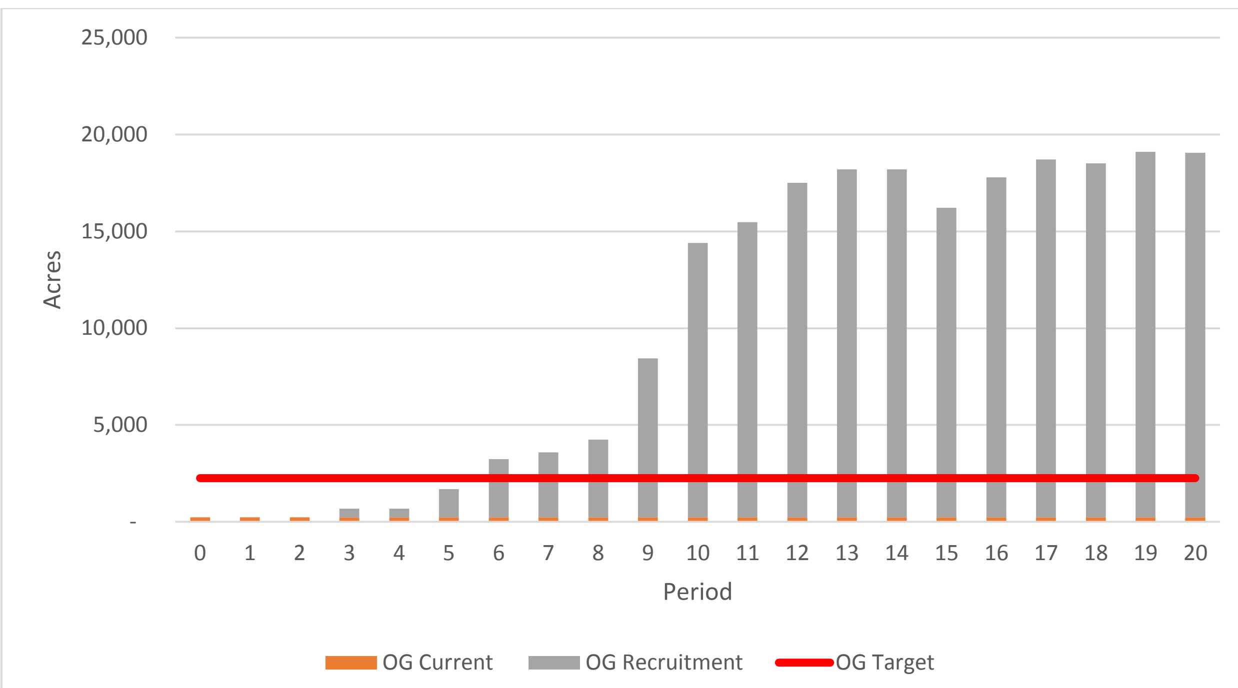


Figure 81: CE Old Growth Acres (Helena) – Grizzly Bear Core Unconstrained

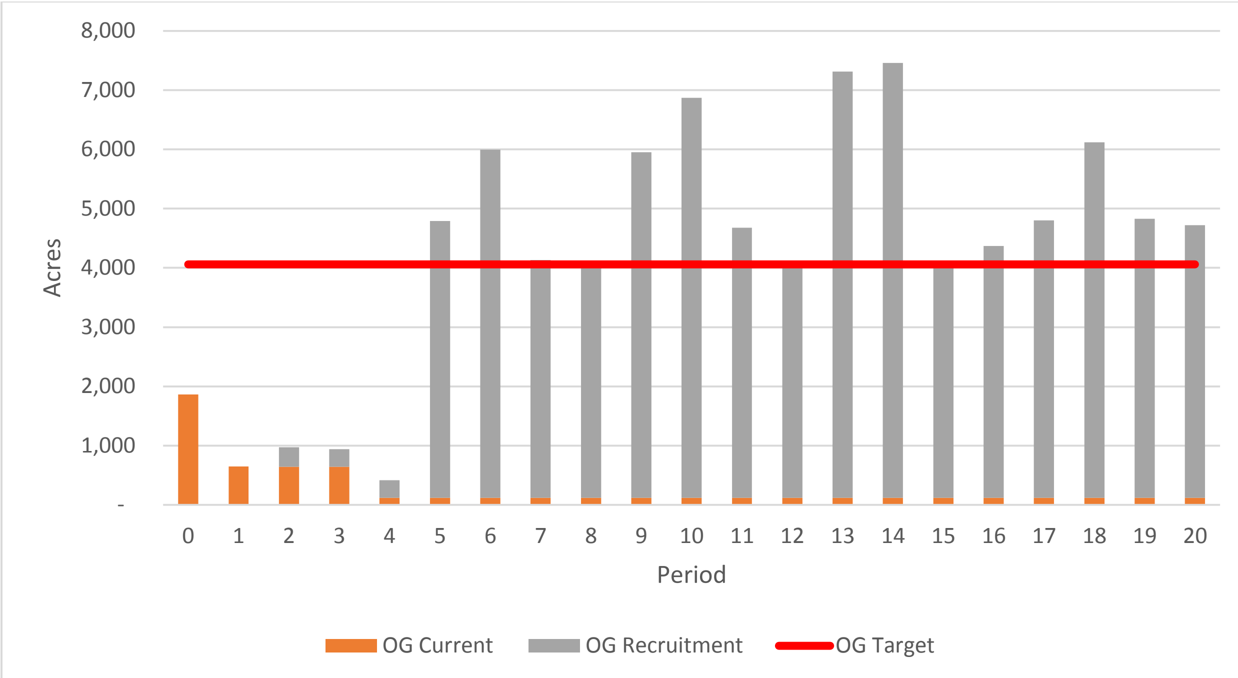


Figure 82: NW Old Growth Acres (Kalispell) – Grizzly Bear Core Unconstrained

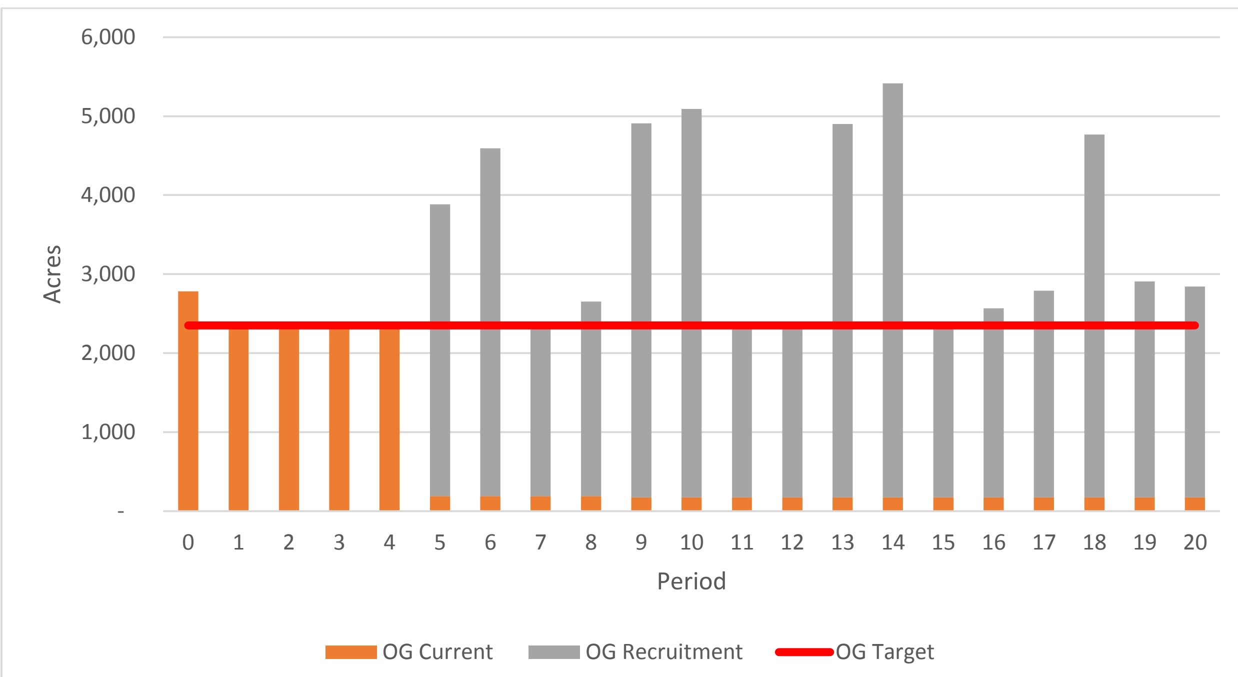


Figure 83: NW Old Growth Acres (Libby) – Grizzly Bear Core Unconstrained

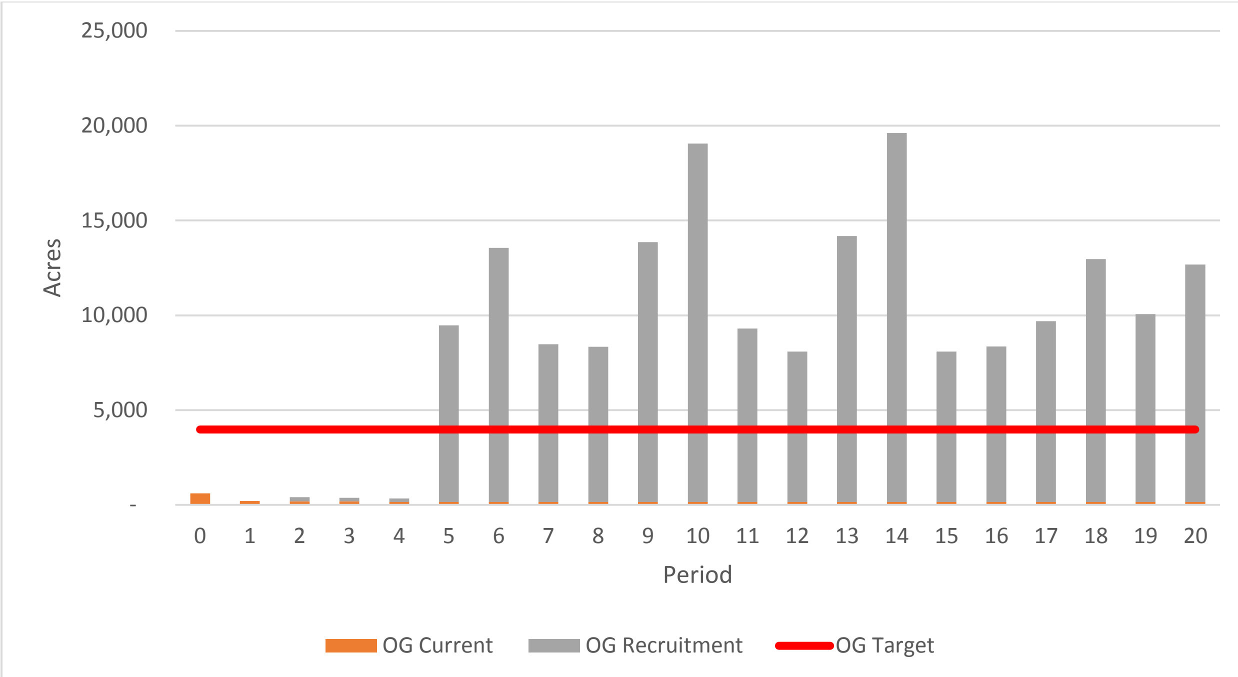


Figure 84: NW Old Growth Acres (Plains) – Grizzly Bear Core Unconstrained

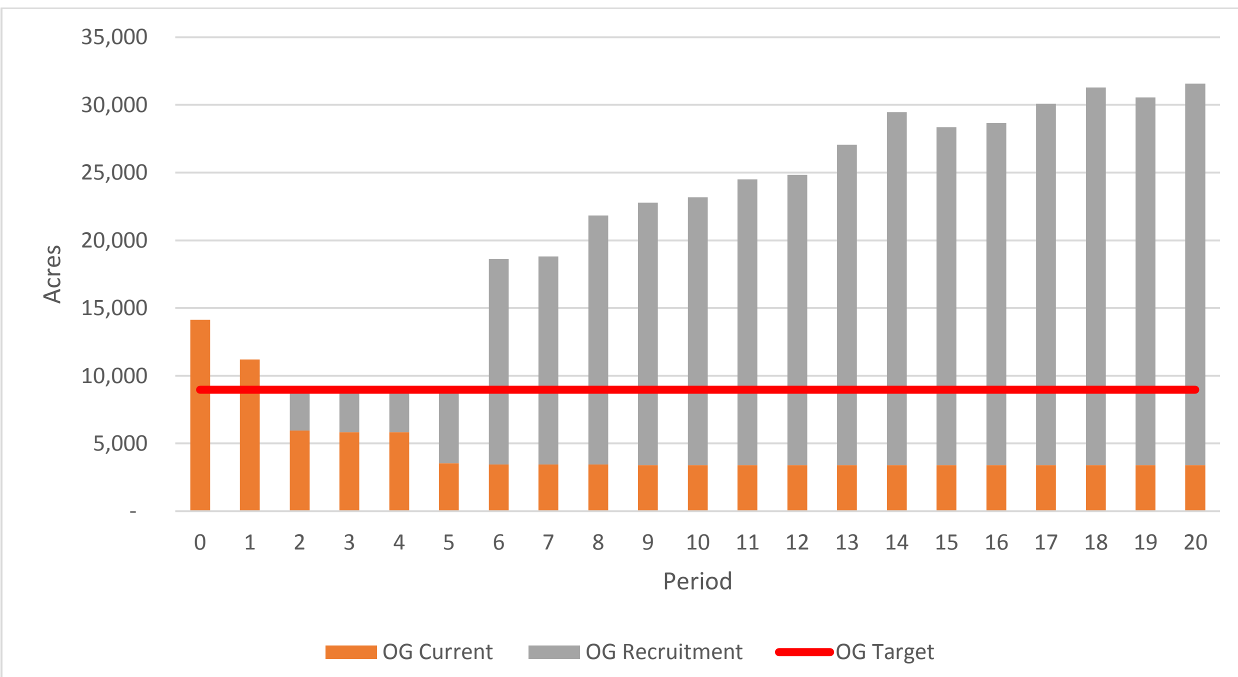


Figure 85: NW Old Growth Acres (Stillwater) – Grizzly Bear Core Unconstrained

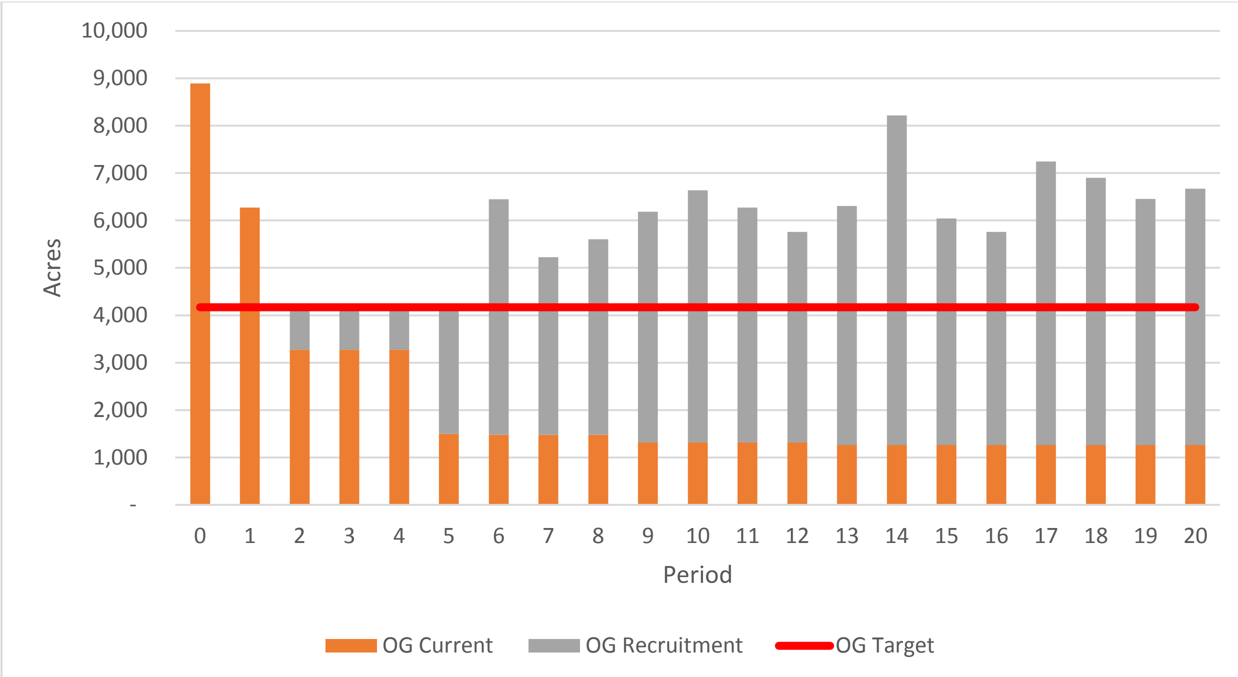


Figure 86: NW Old Growth Acres (Swan) – Grizzly Bear Core Unconstrained

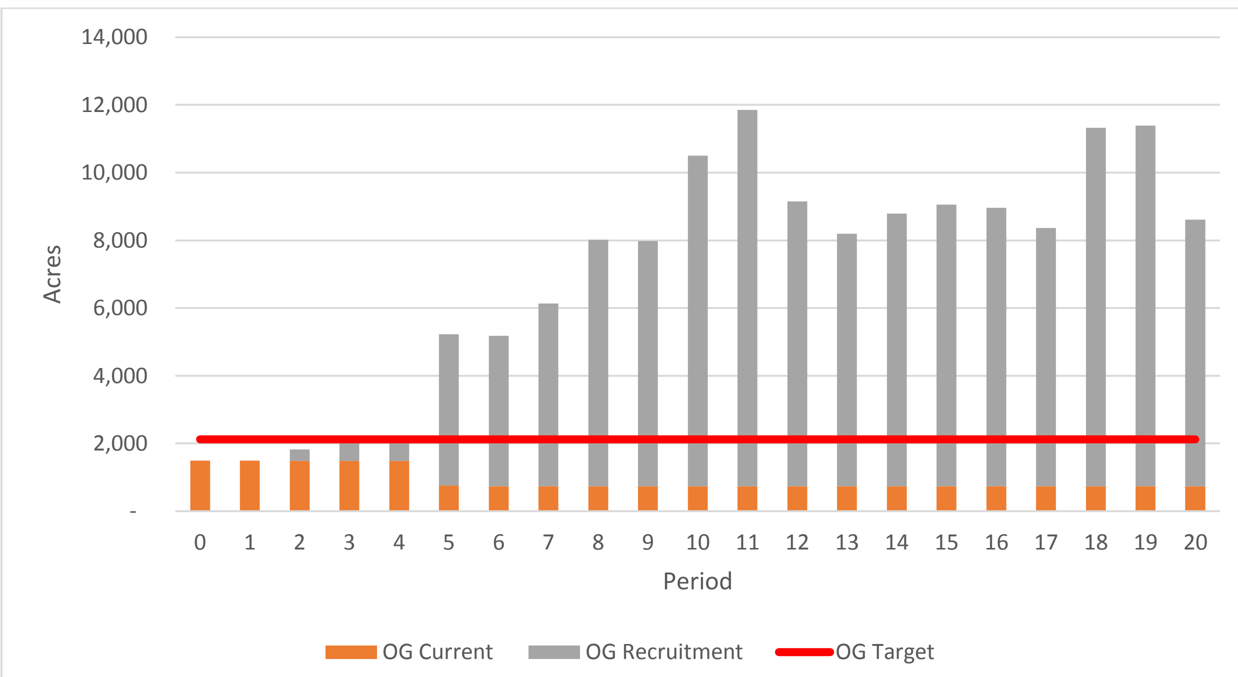


Figure 87: SW Old Growth Acres (Anaconda) – Grizzly Bear Core Unconstrained

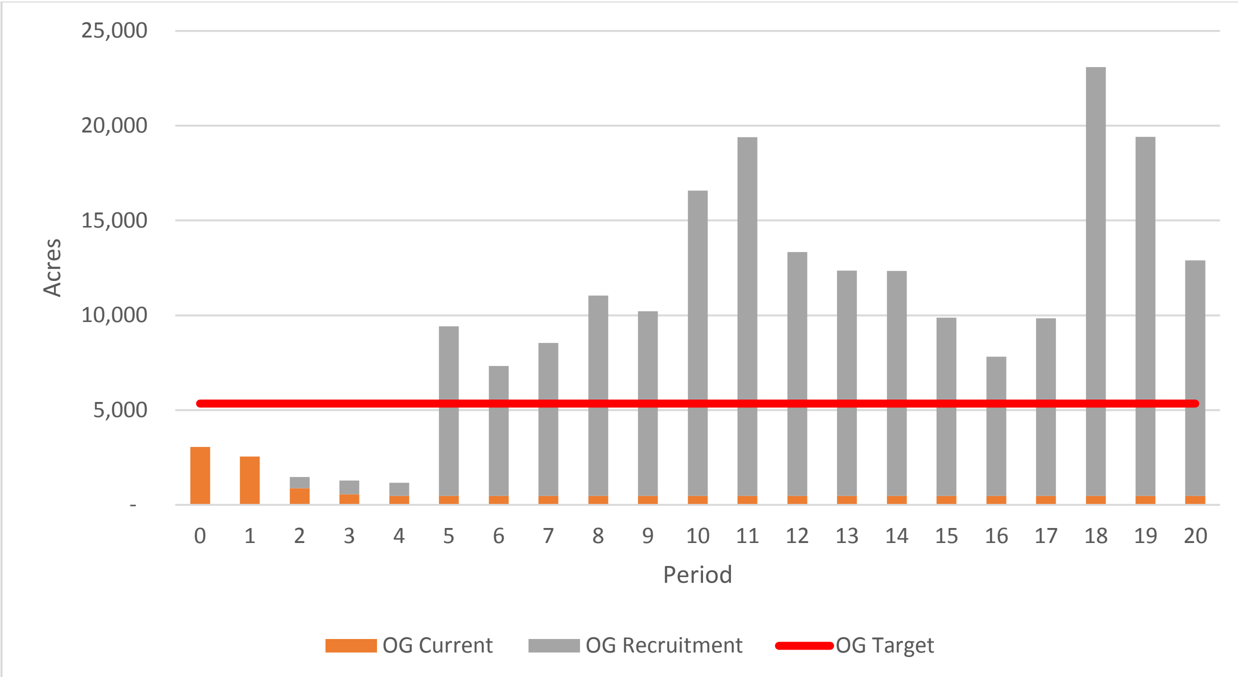


Figure 88: SW Old Growth Acres (Clearwater) – Grizzly Bear Core Unconstrained

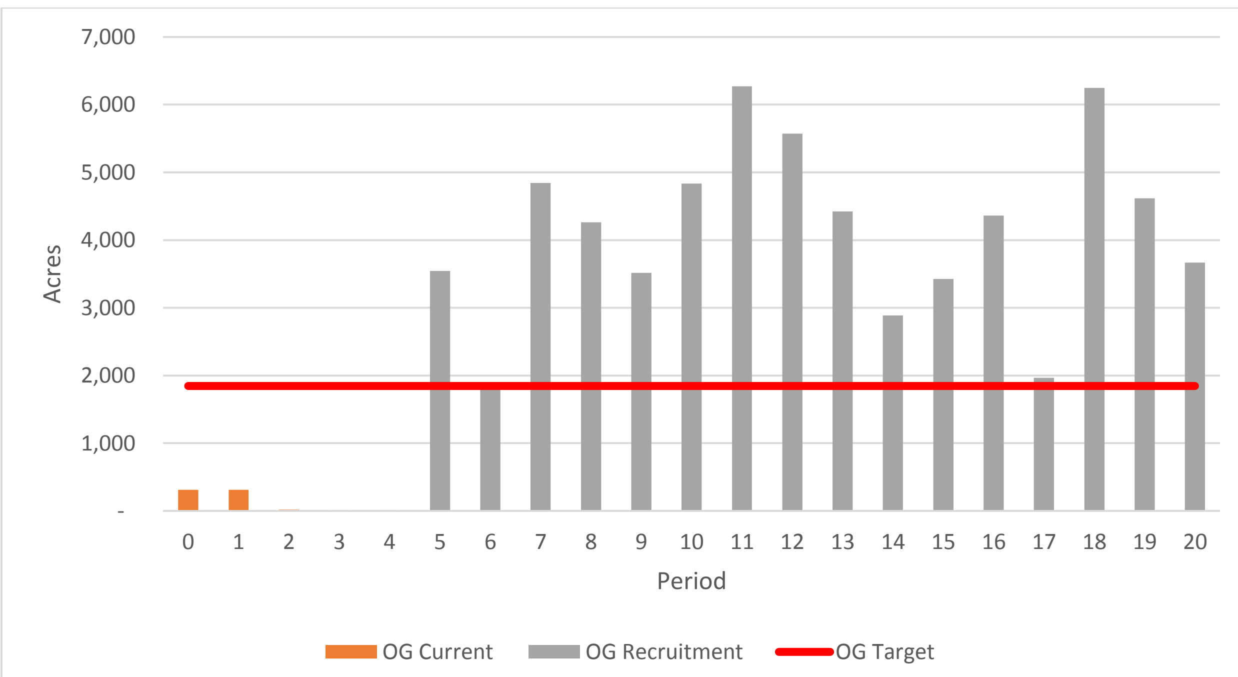


Figure 89: SW Old Growth Acres (Hamilton) – Grizzly Bear Core Unconstrained

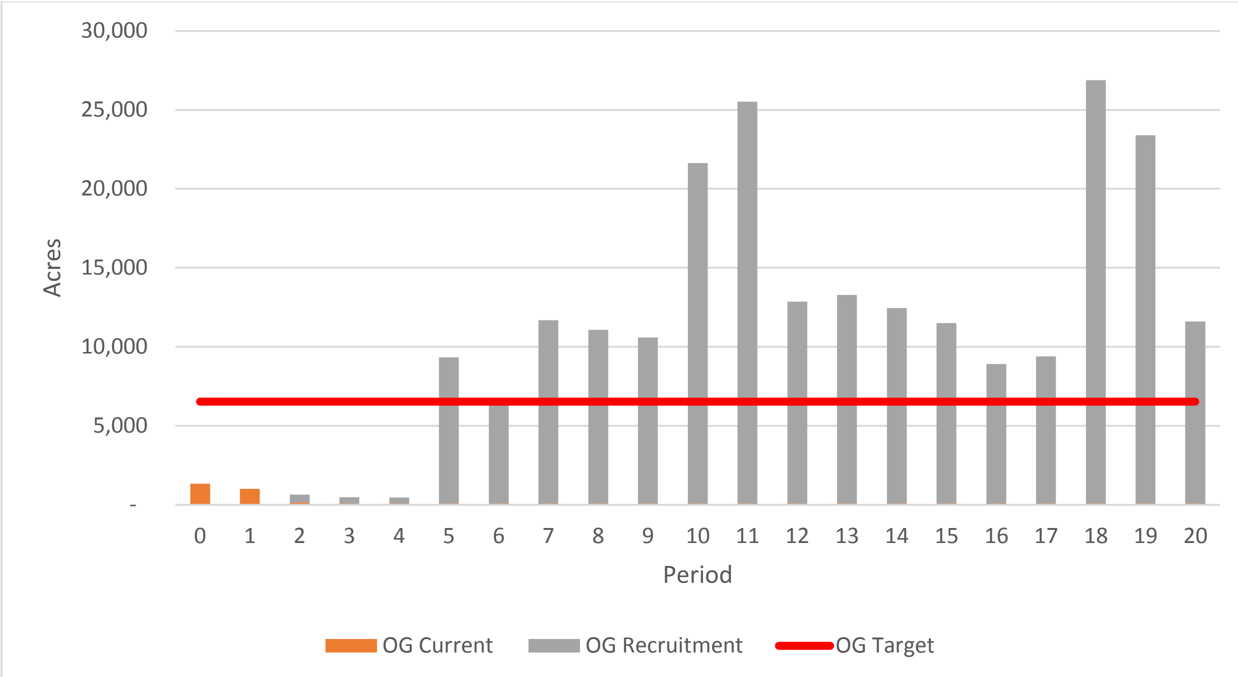


Figure 90: SW Old Growth Acres (Missoula) – Grizzly Bear Core Unconstrained

20.2 Constrained Grizzly Bear Core Acres

The following charts show selected results from the final LP model run with constrained Grizzly Bear Core acres (active management not allowed within the Core).

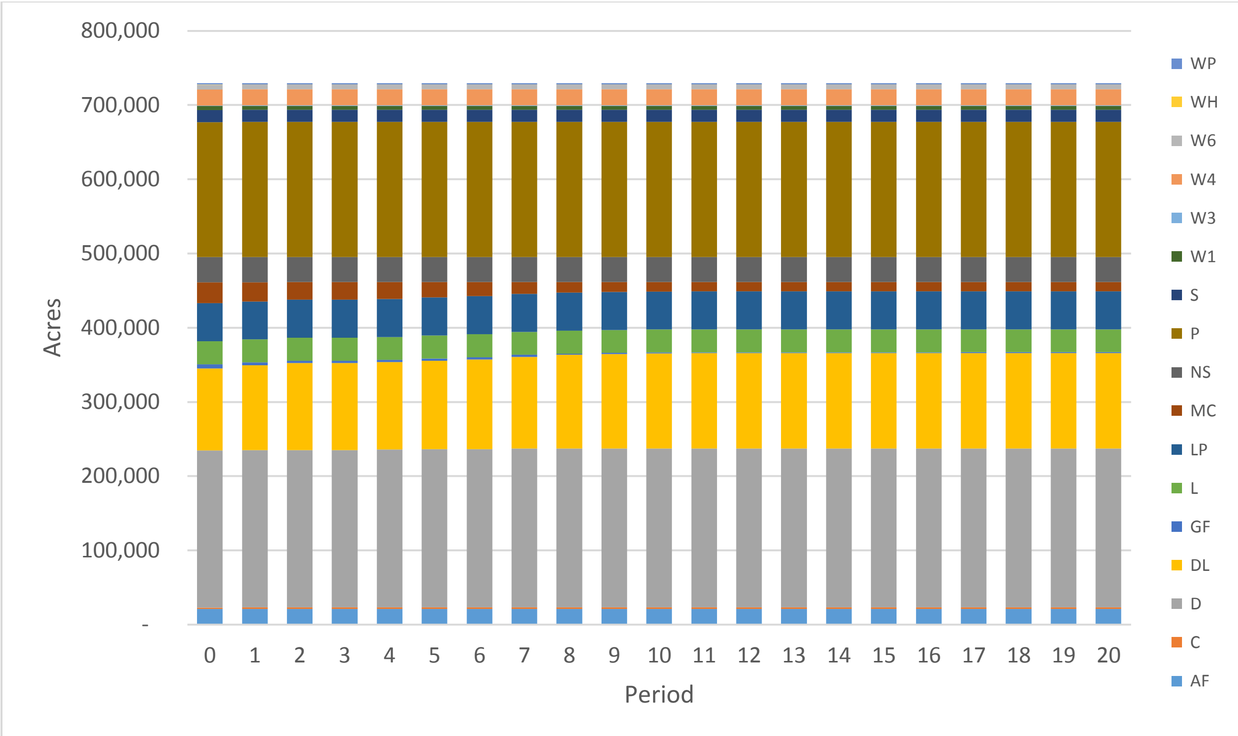


Figure 91: Acres by Species – Grizzly Bear Core Constrained

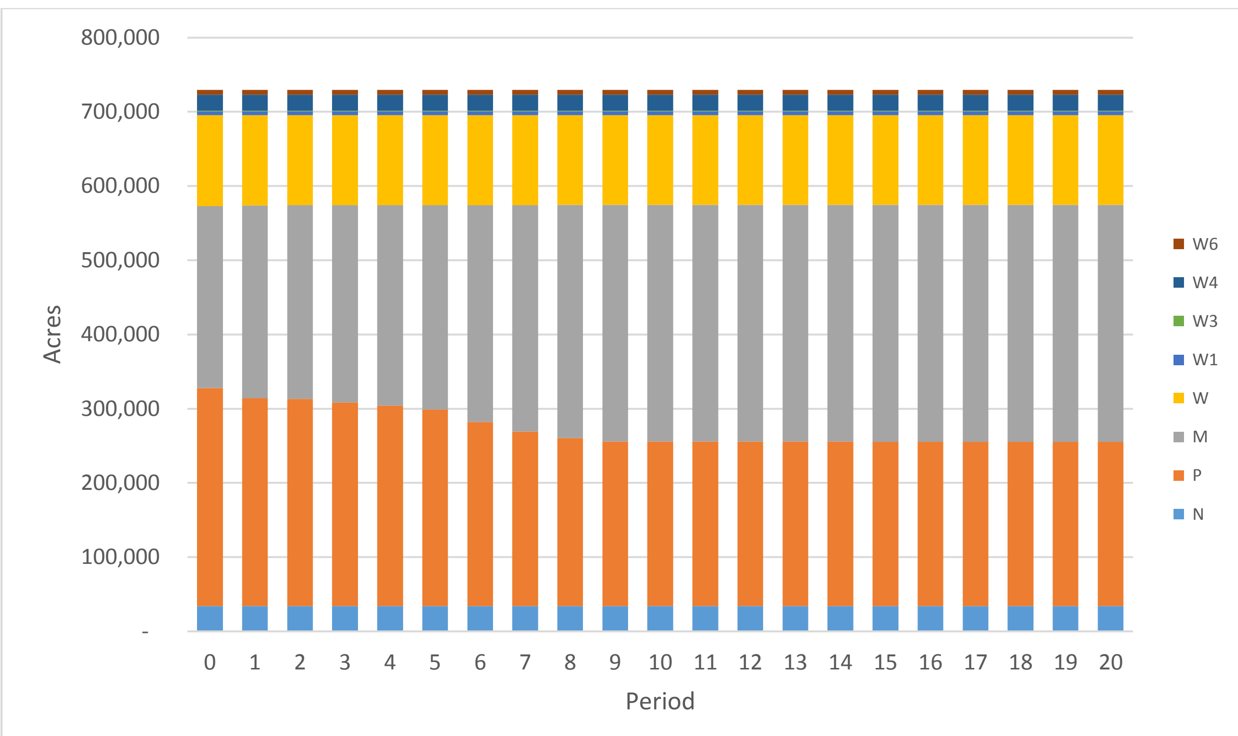


Figure 92: Acres by Stocking – Grizzly Bear Core Constrained

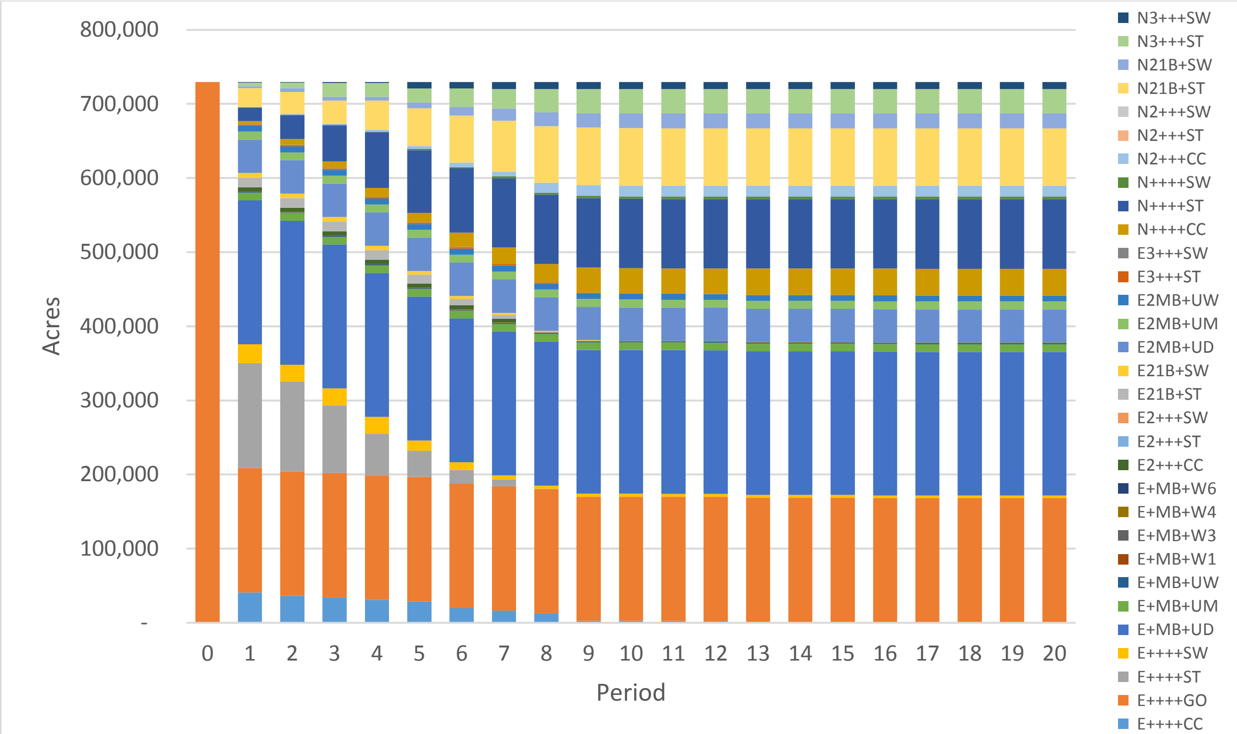


Figure 93: Management Pathway Acres – Grizzly Bear Core Constrained

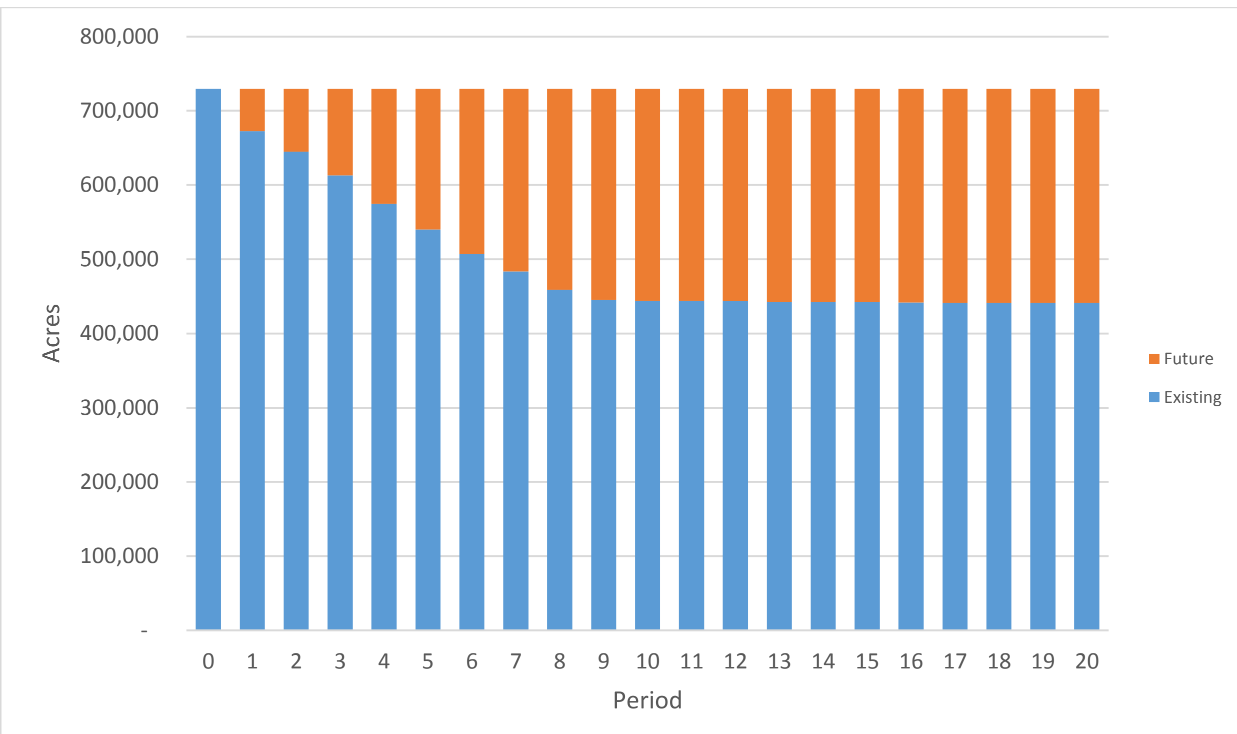


Figure 94: Existing vs. Future Rotation Acres – Grizzly Bear Core Constrained

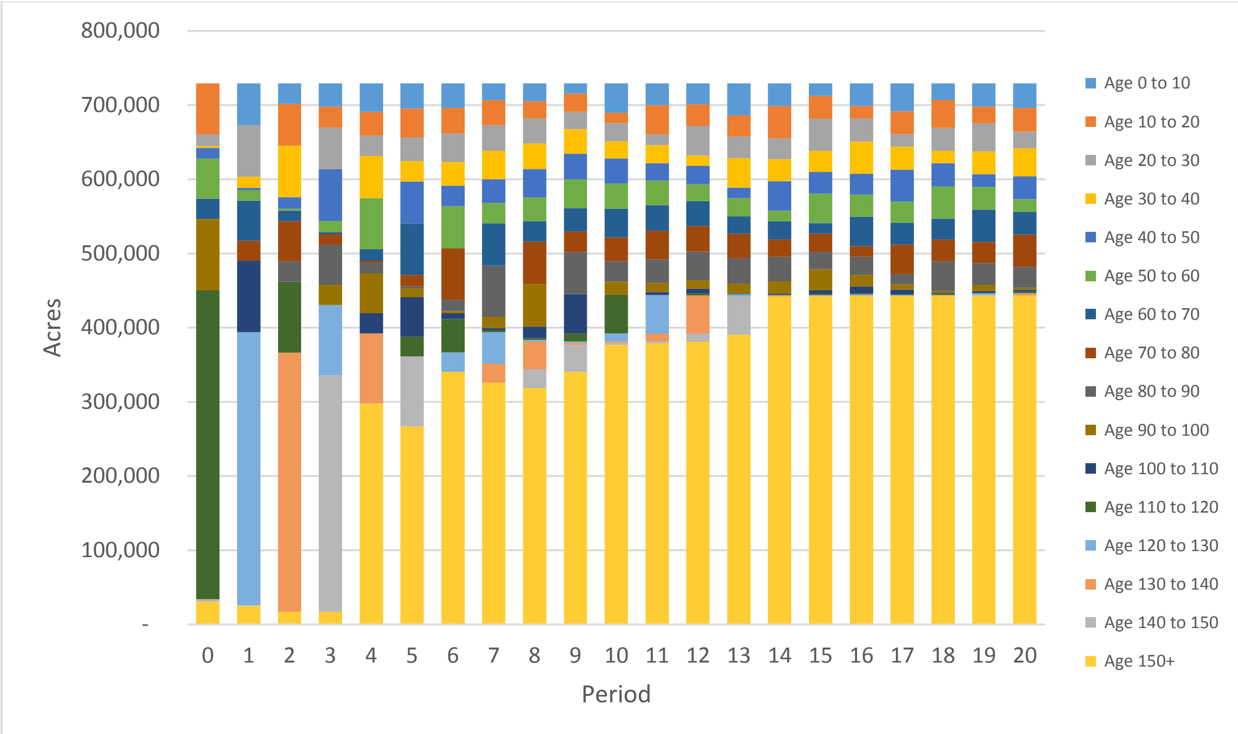


Figure 95: Age Class Distribution – Grizzly Bear Core Constrained

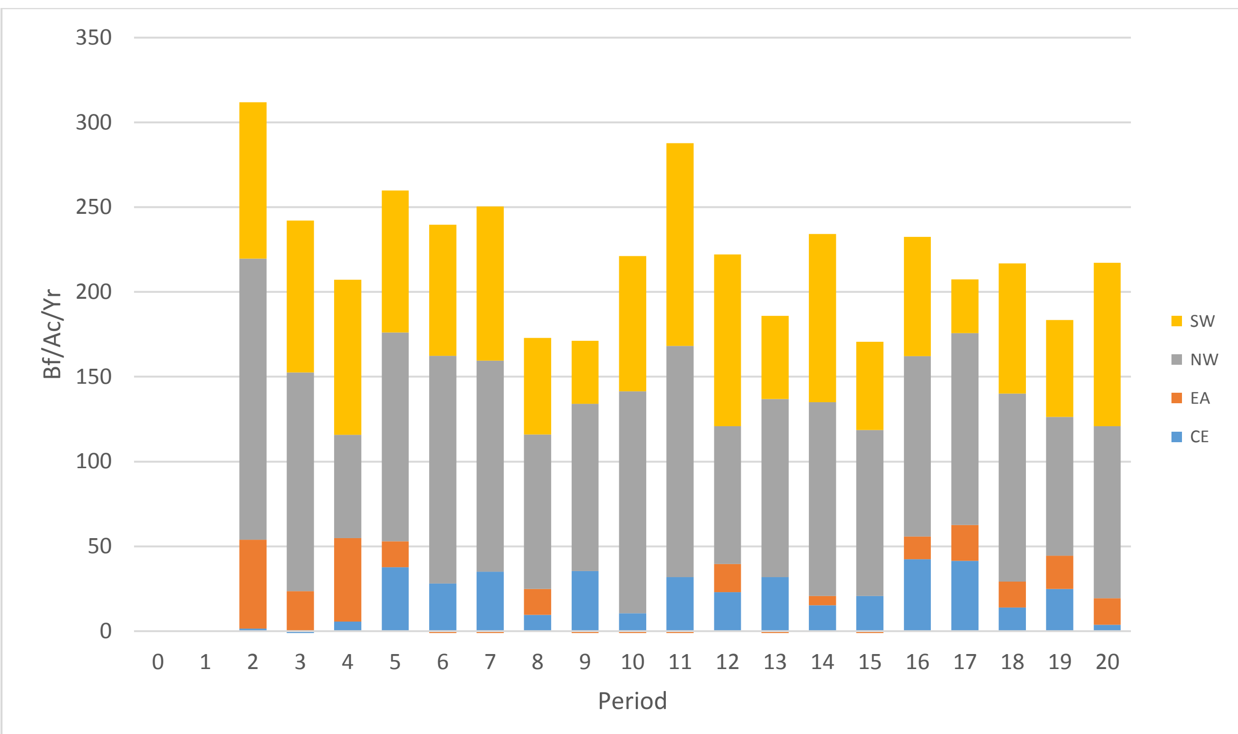


Figure 96: Average Annual Growth Rate – Grizzly Bear Core Constrained

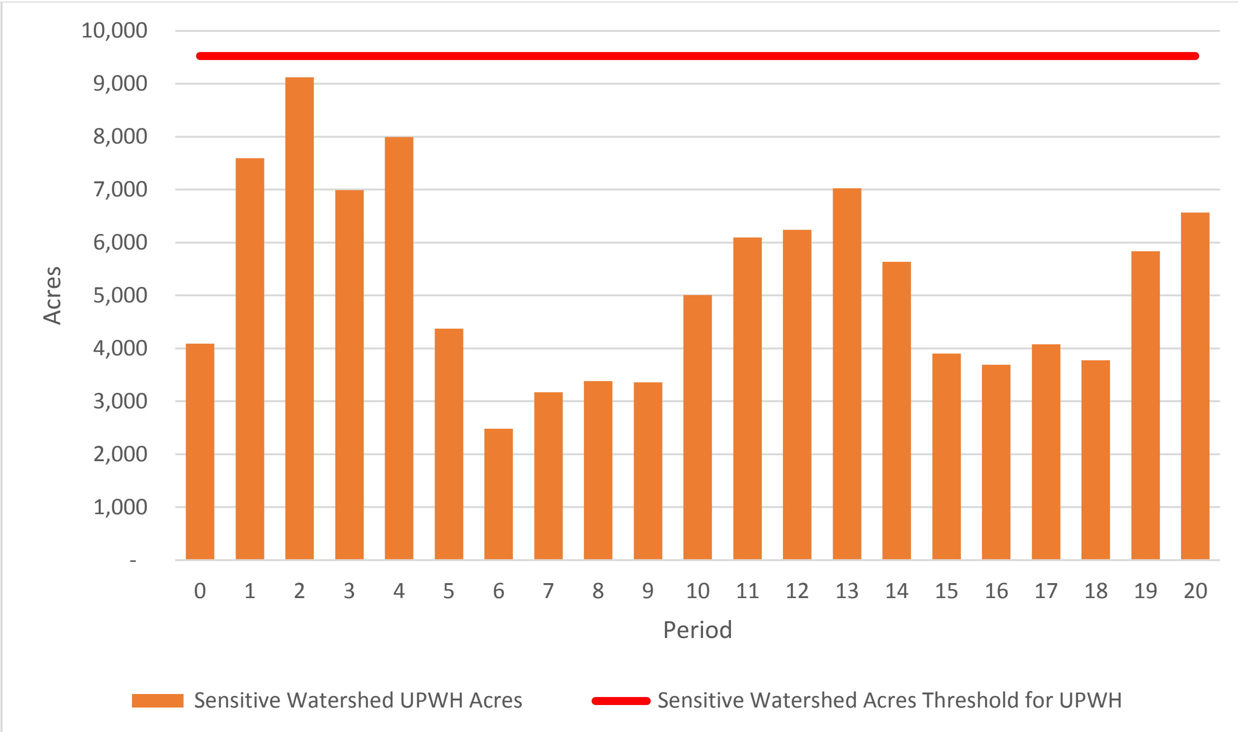


Figure 97: Sensitive Watershed Development (UPWH) – Grizzly Bear Core Constrained

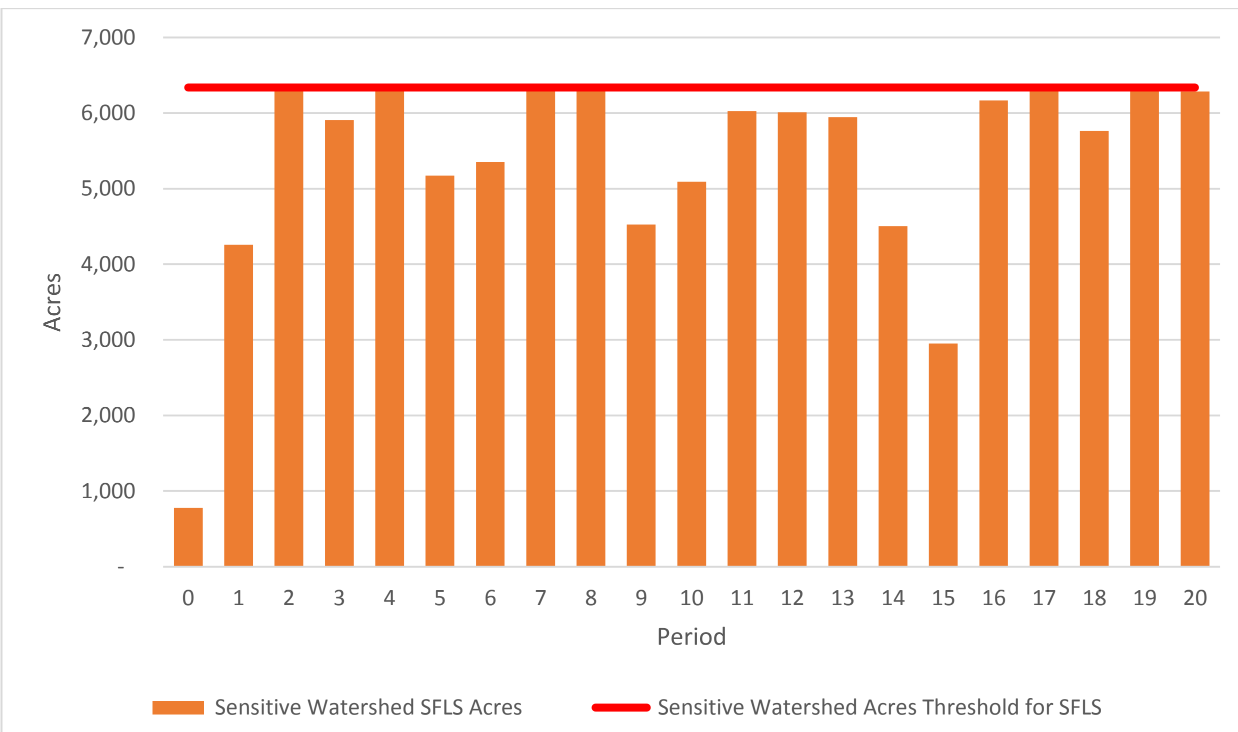


Figure 98: Sensitive Watershed Development (SFLS) – Grizzly Bear Core Constrained

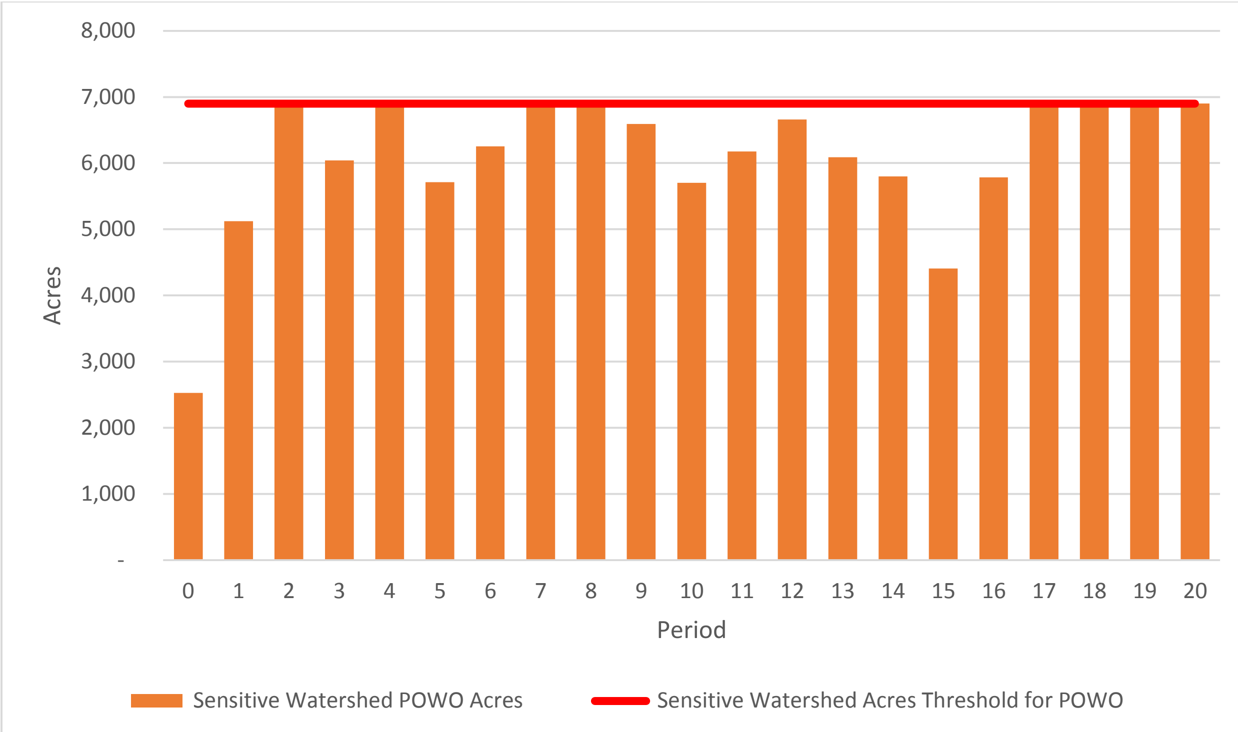


Figure 99: Sensitive Watershed Development (POWO) – Grizzly Bear Core Constrained

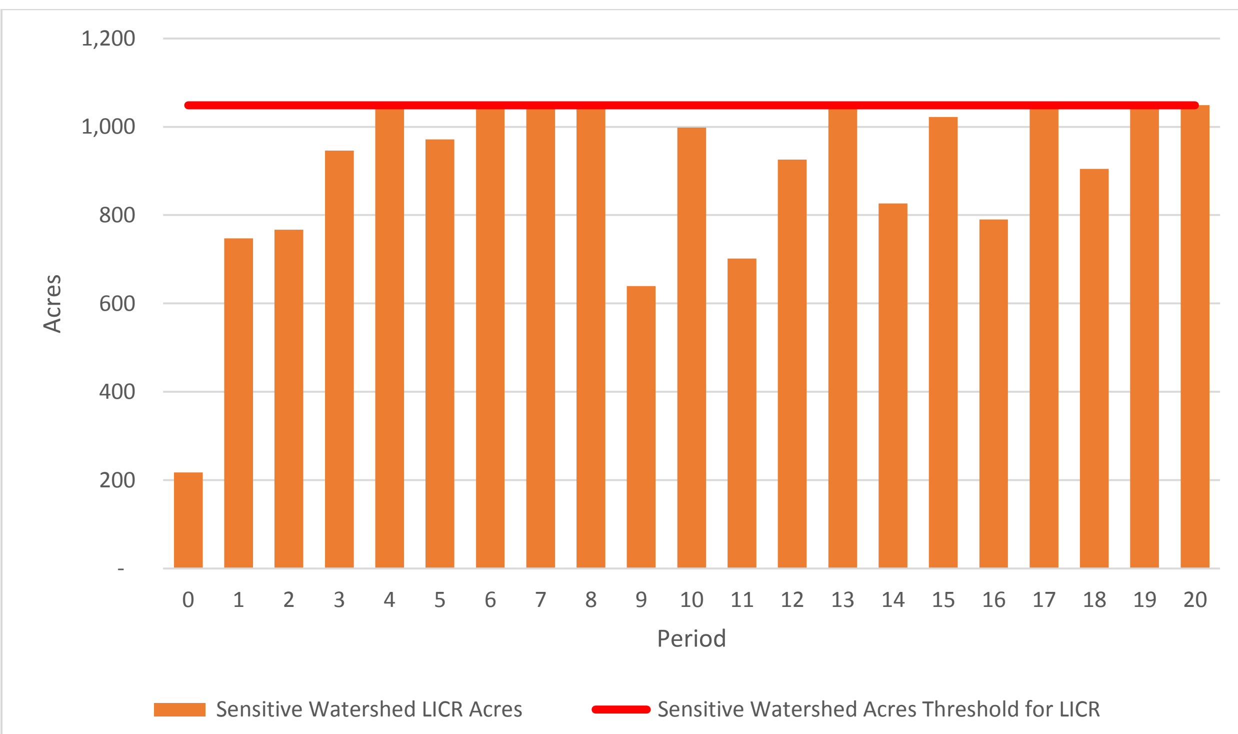


Figure 100: Sensitive Watershed Development (LICR) – Grizzly Bear Core Constrained

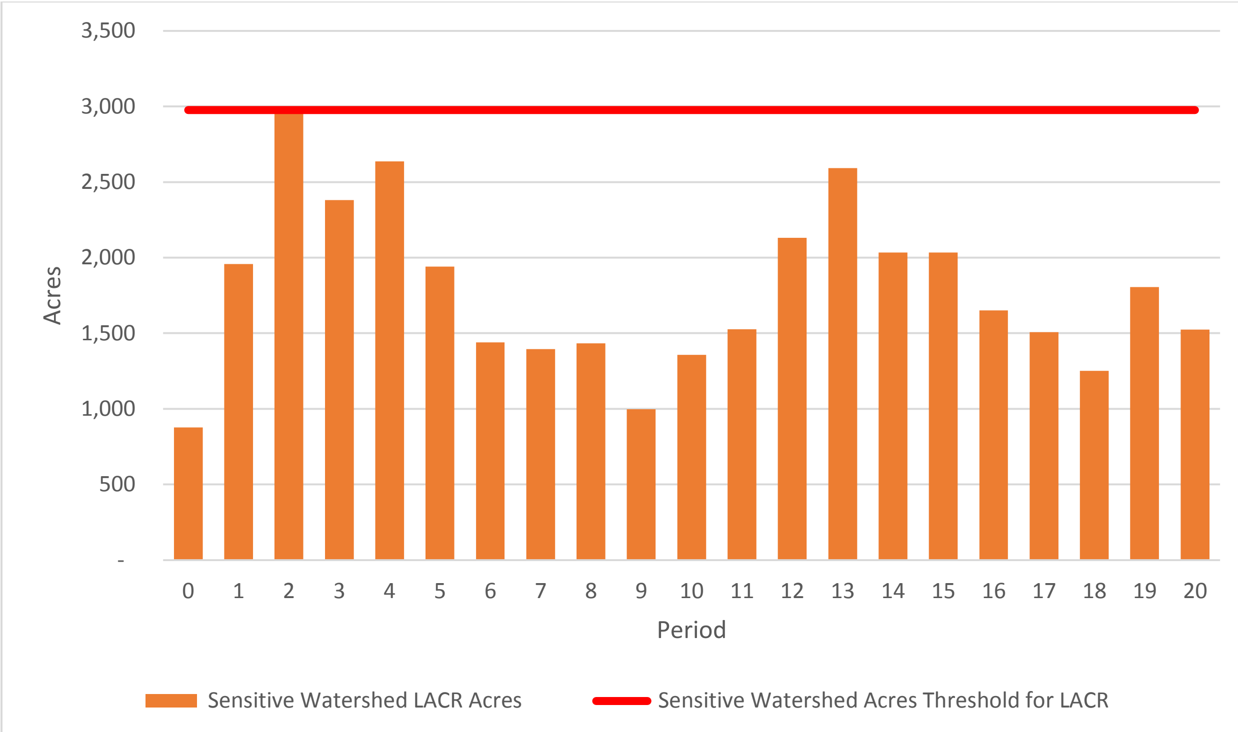


Figure 101: Sensitive Watershed Development (LACR) – Grizzly Bear Core Constrained

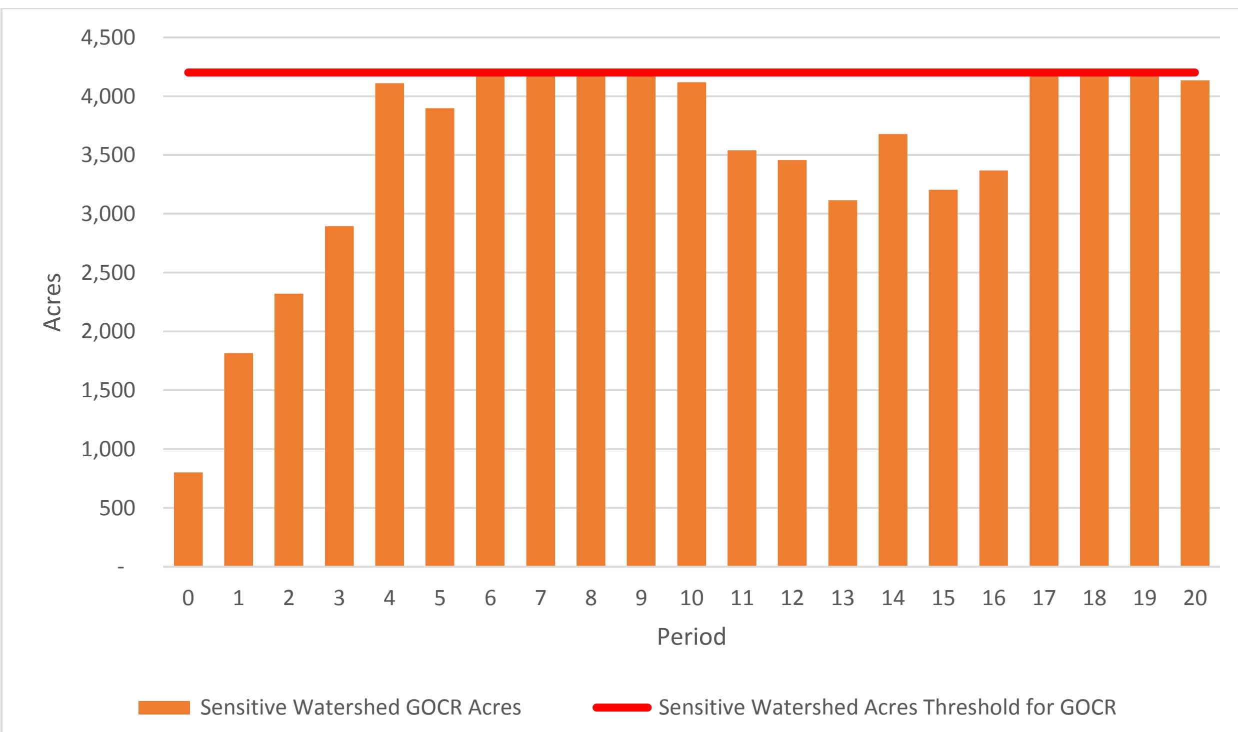


Figure 102: Sensitive Watershed Development (GOCR) – Grizzly Bear Core Constrained

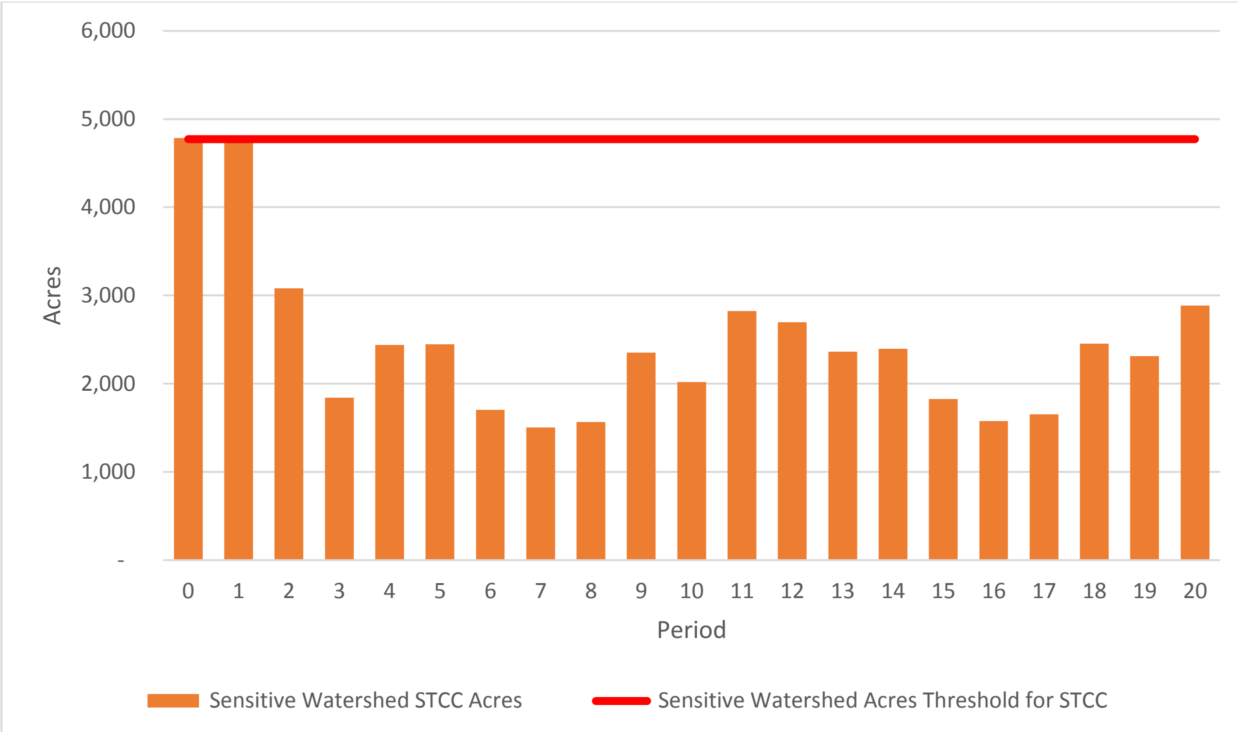


Figure 103: Sensitive Watershed Development (STCC) – Grizzly Bear Core Constrained

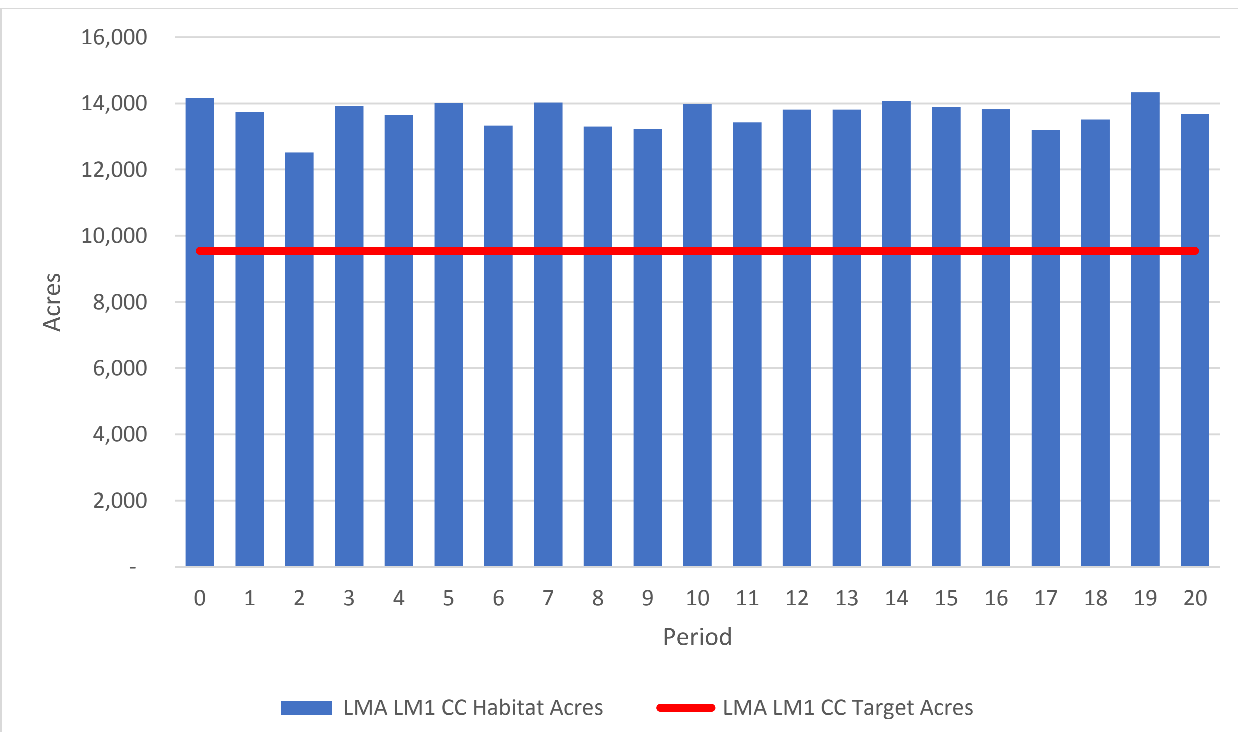


Figure 104: LMA (Coal Creek) Cover Acres – Grizzly Bear Core Constrained

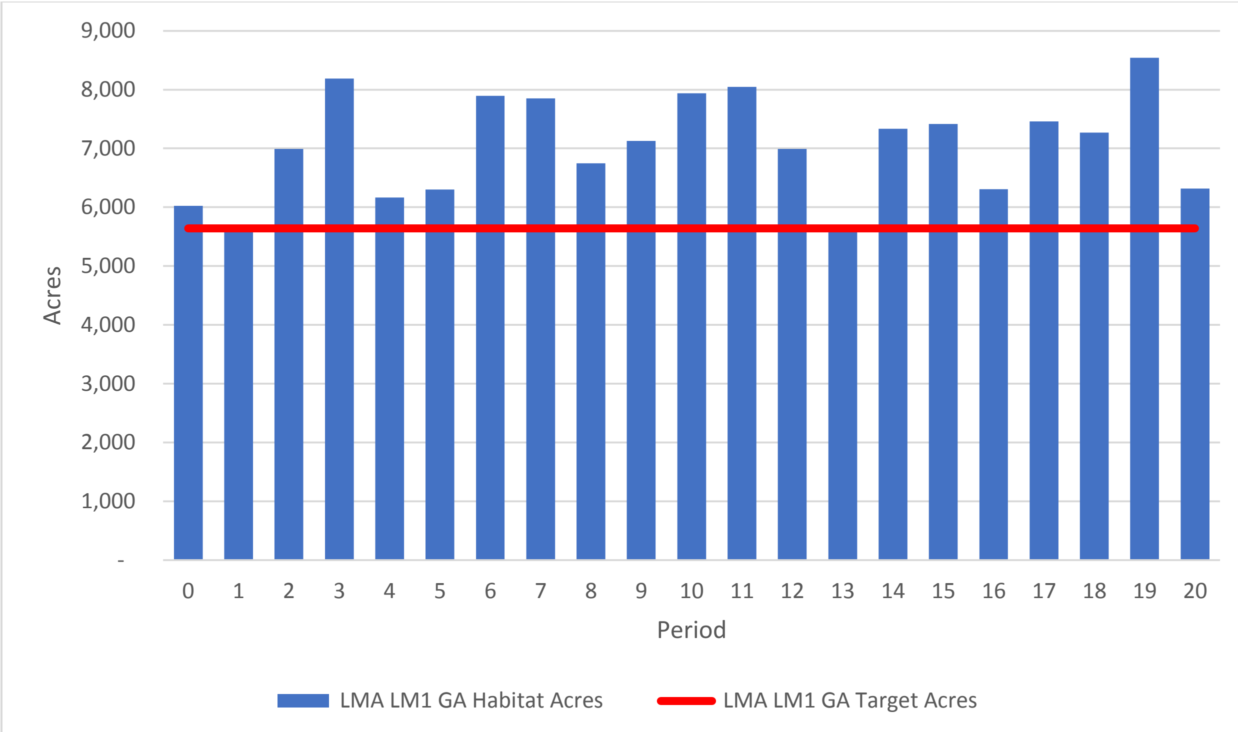


Figure 105: LMA (Garnet) Cover Acres – Grizzly Bear Core Constrained

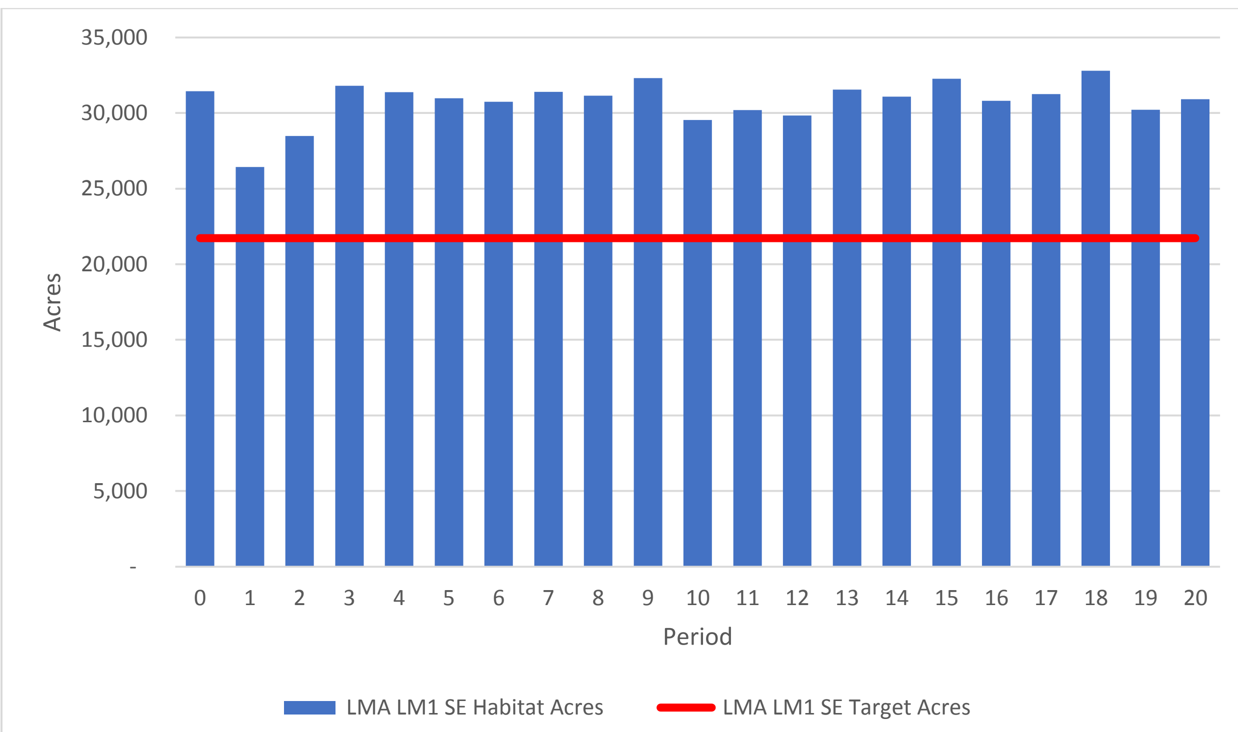


Figure 106: LMA (Stillwater East) Cover Acres – Grizzly Bear Core Constrained

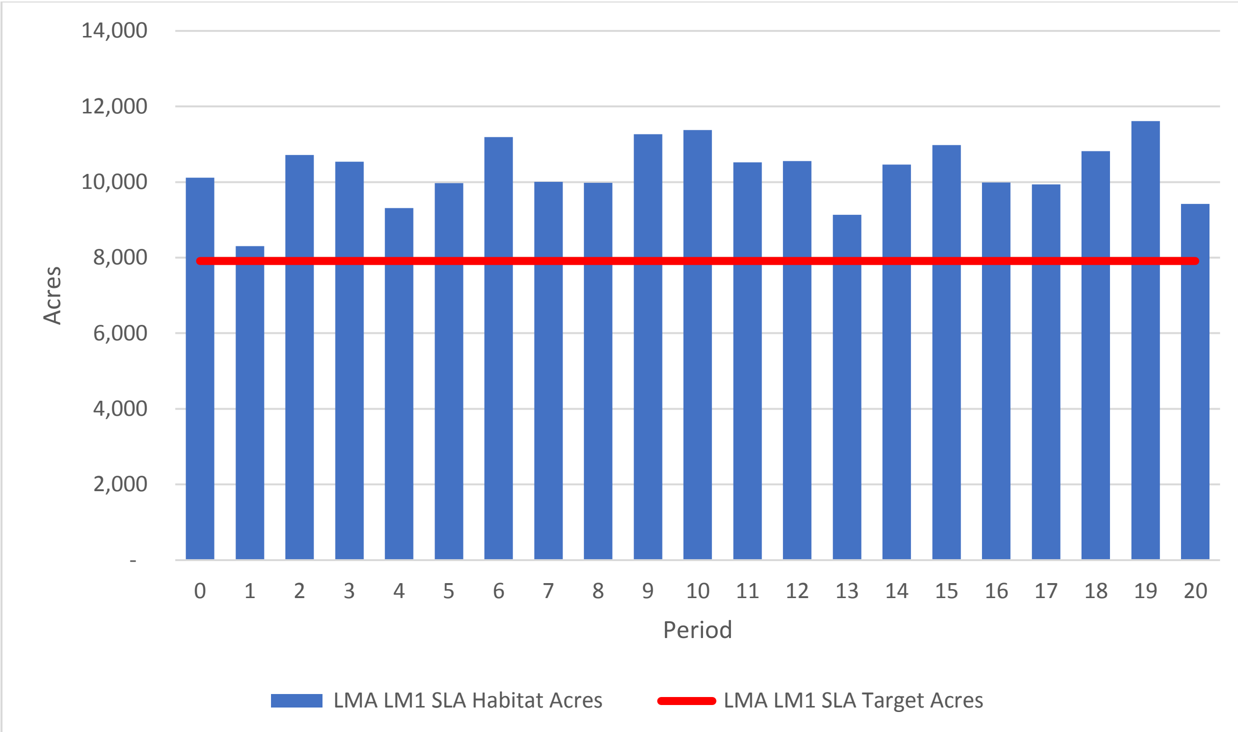


Figure 107: LMA (Seeley Lake) Cover Acres – Grizzly Bear Core Constrained

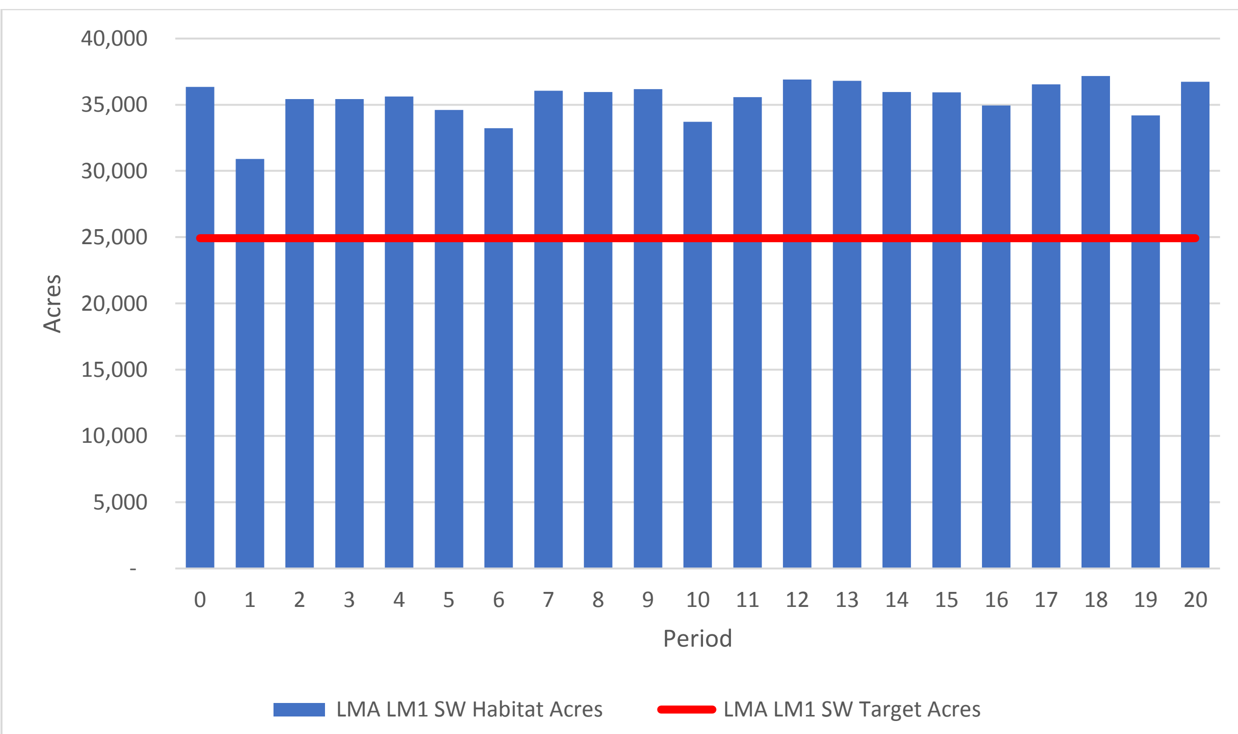


Figure 108: LMA (Stillwater West) Cover Acres – Grizzly Bear Core Constrained

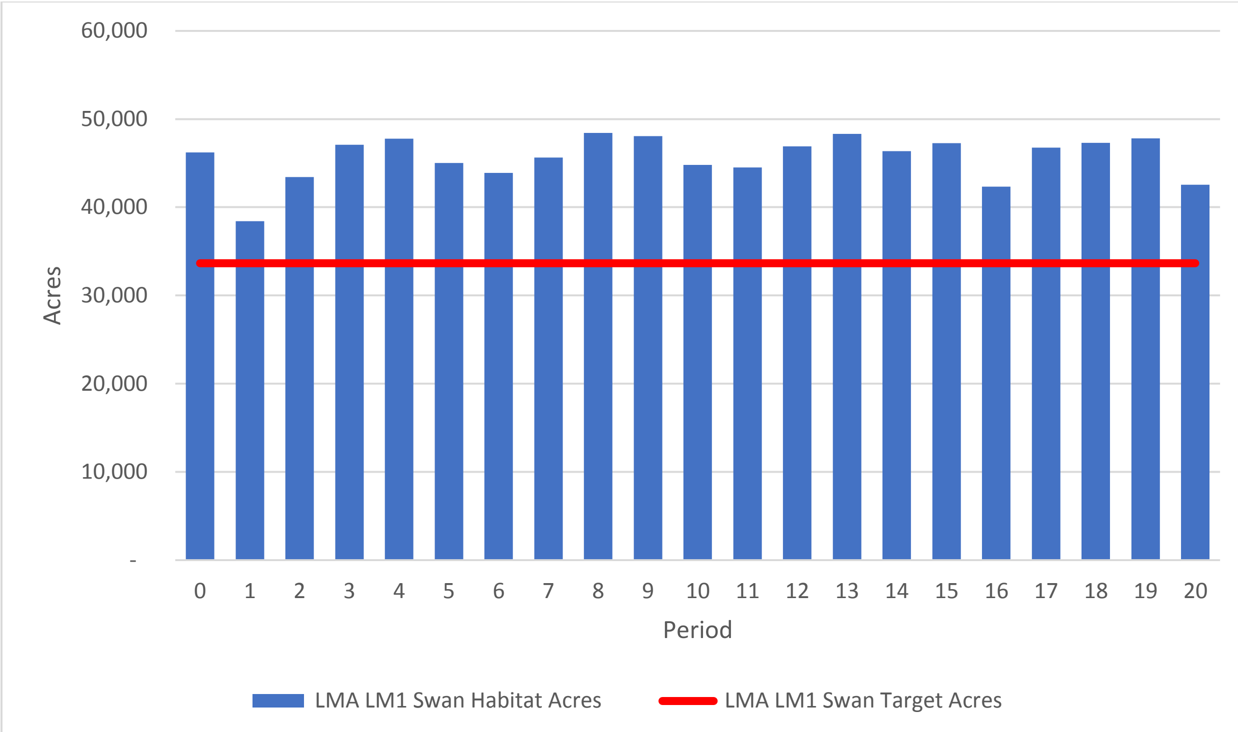


Figure 109: LMA (Swan) Cover Acres – Grizzly Bear Core Constrained

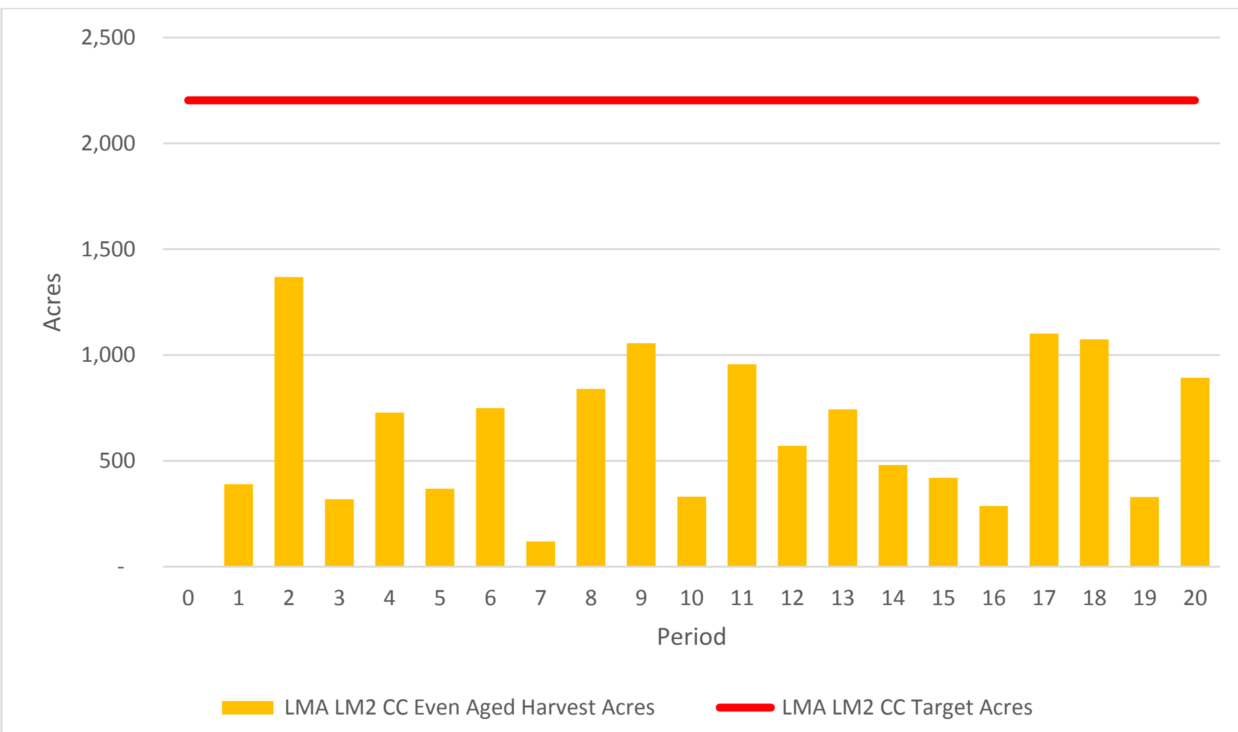


Figure 110: LMA (Coal Creek) EA Harvest Acres – Grizzly Bear Core Constrained

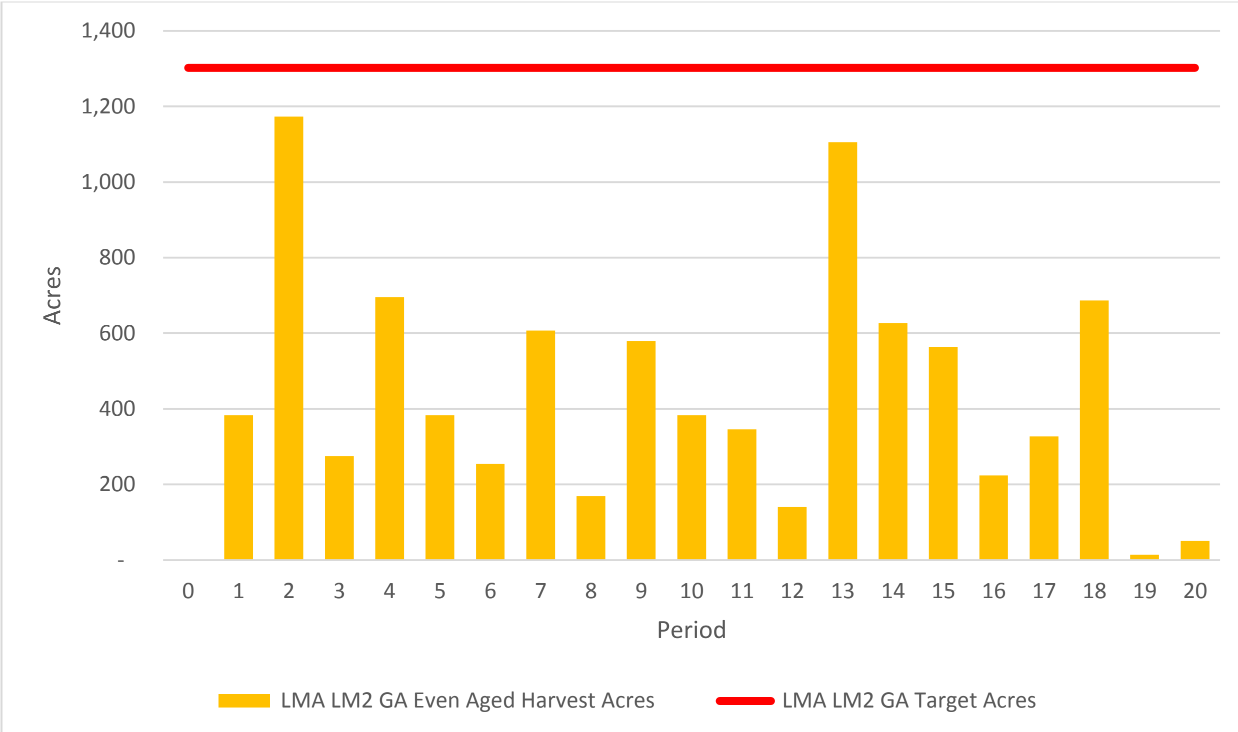


Figure 111: LMA (Garnet) EA Harvest Acres – Grizzly Bear Core Constrained

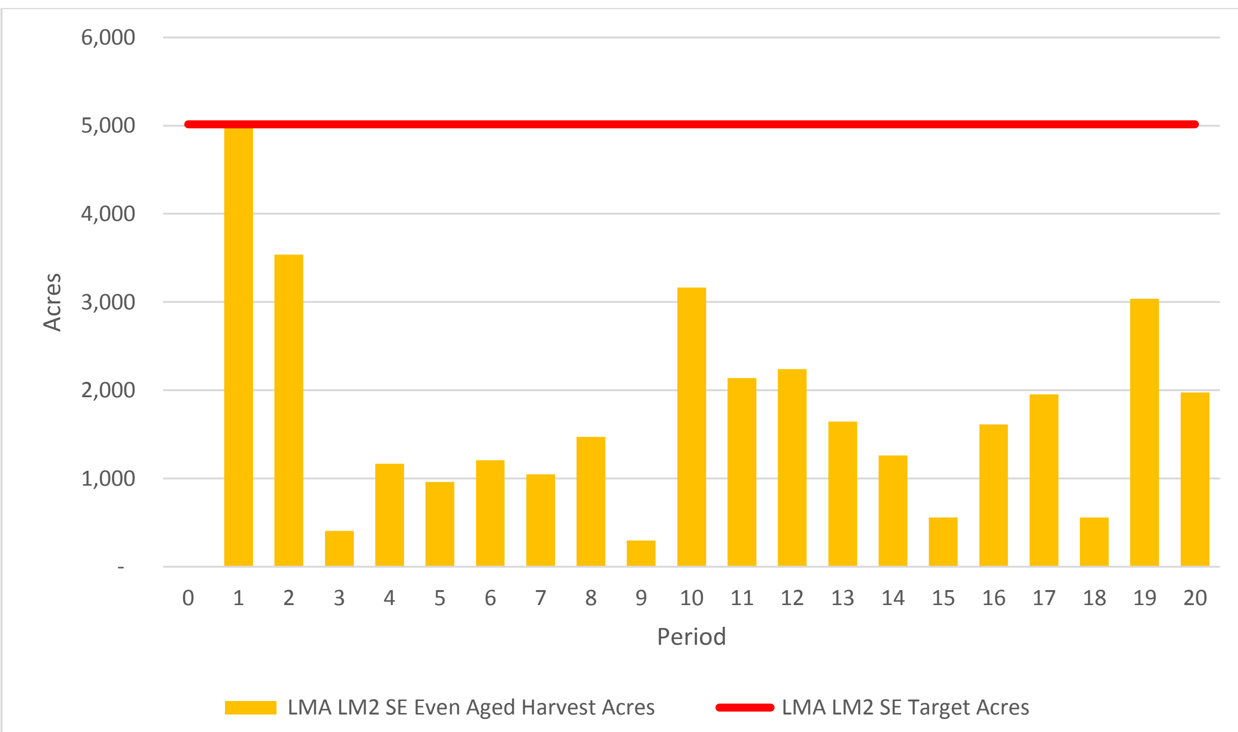


Figure 112: LMA (Stillwater East) EA Harvest Acres – Grizzly Bear Core Constrained

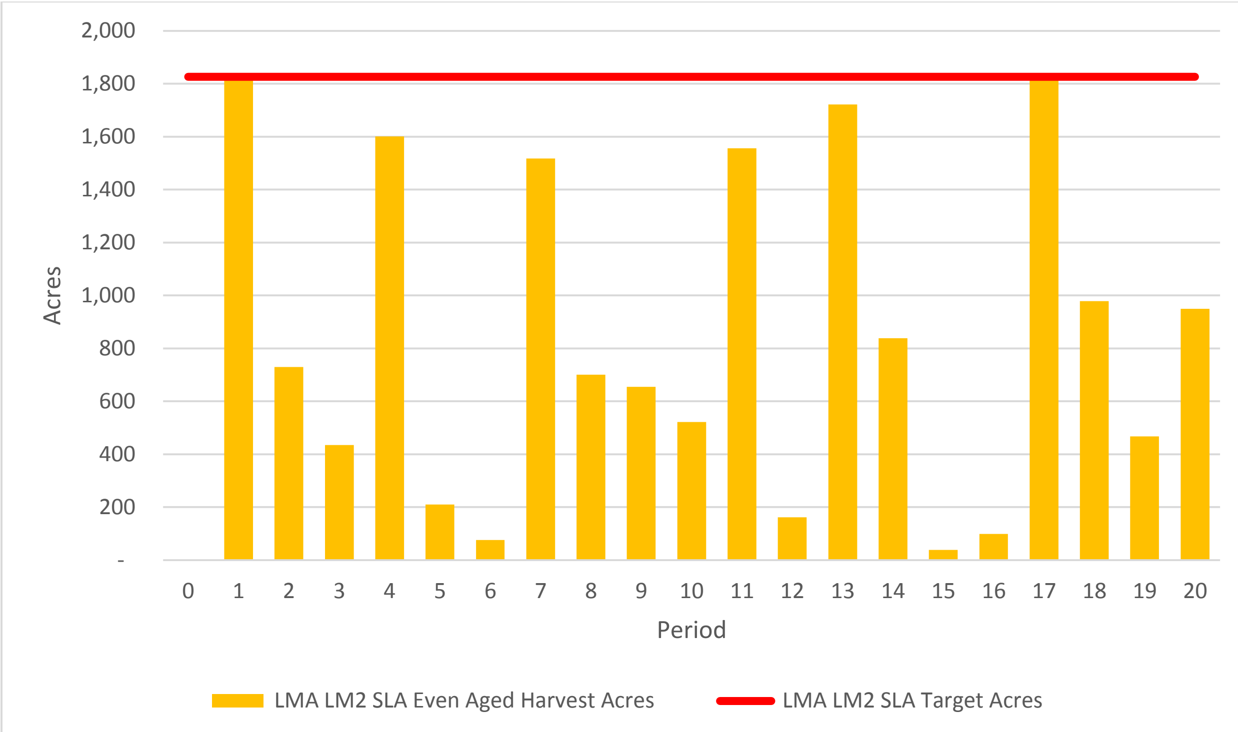


Figure 113: LMA (Seeley Lake) EA Harvest Acres – Grizzly Bear Core Constrained

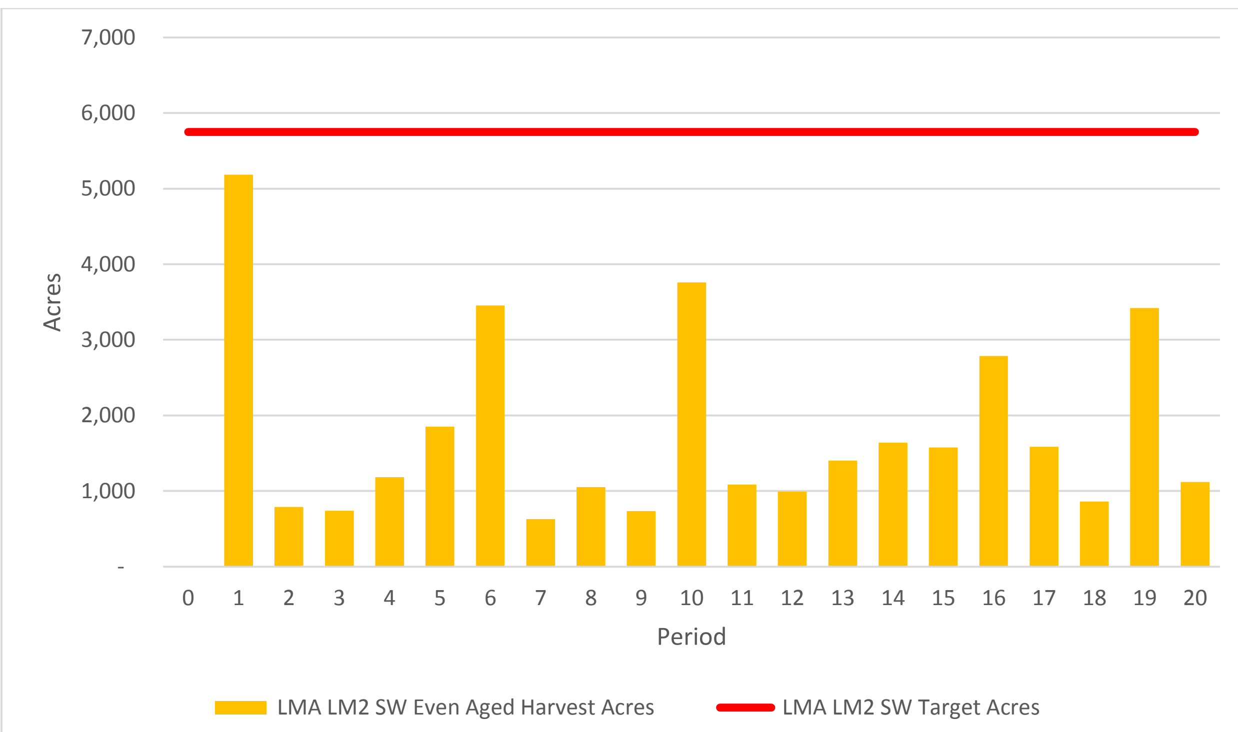


Figure 114: LMA (Stillwater West) EA Harvest Acres – Grizzly Bear Core Constrained

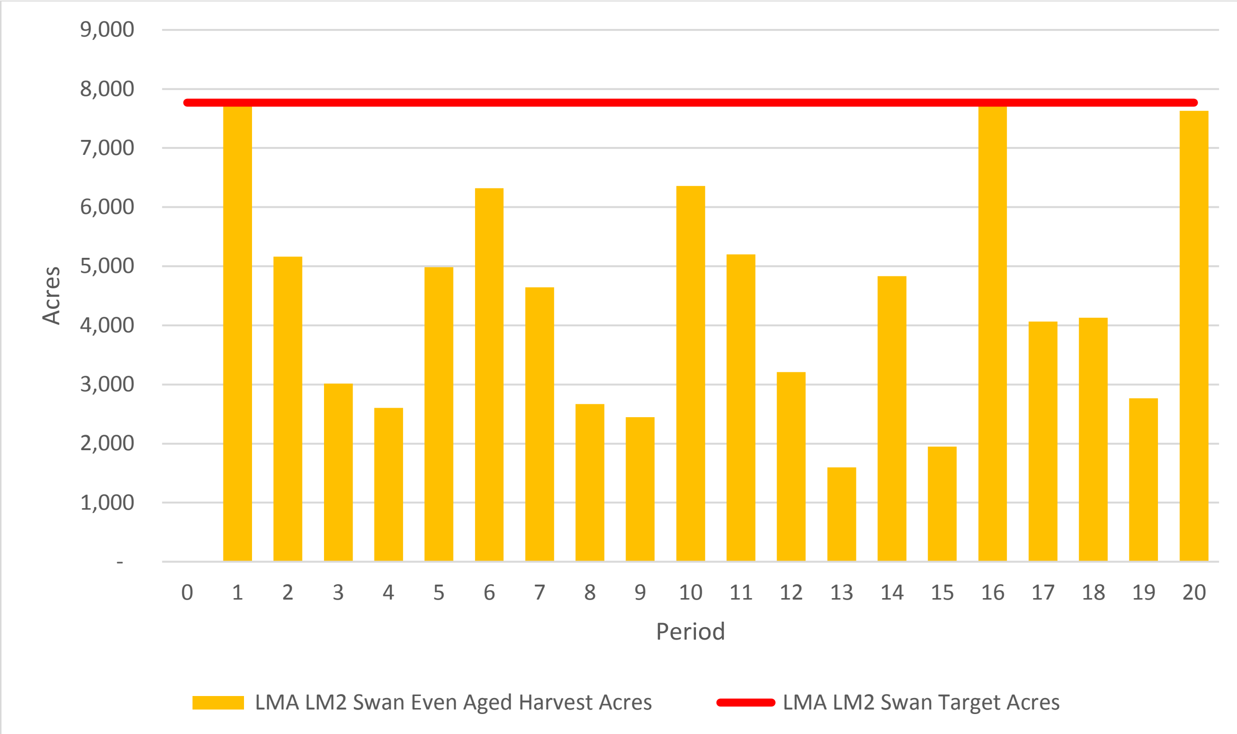


Figure 115: LMA (Swan) EA Harvest Acres – Grizzly Bear Core Constrained

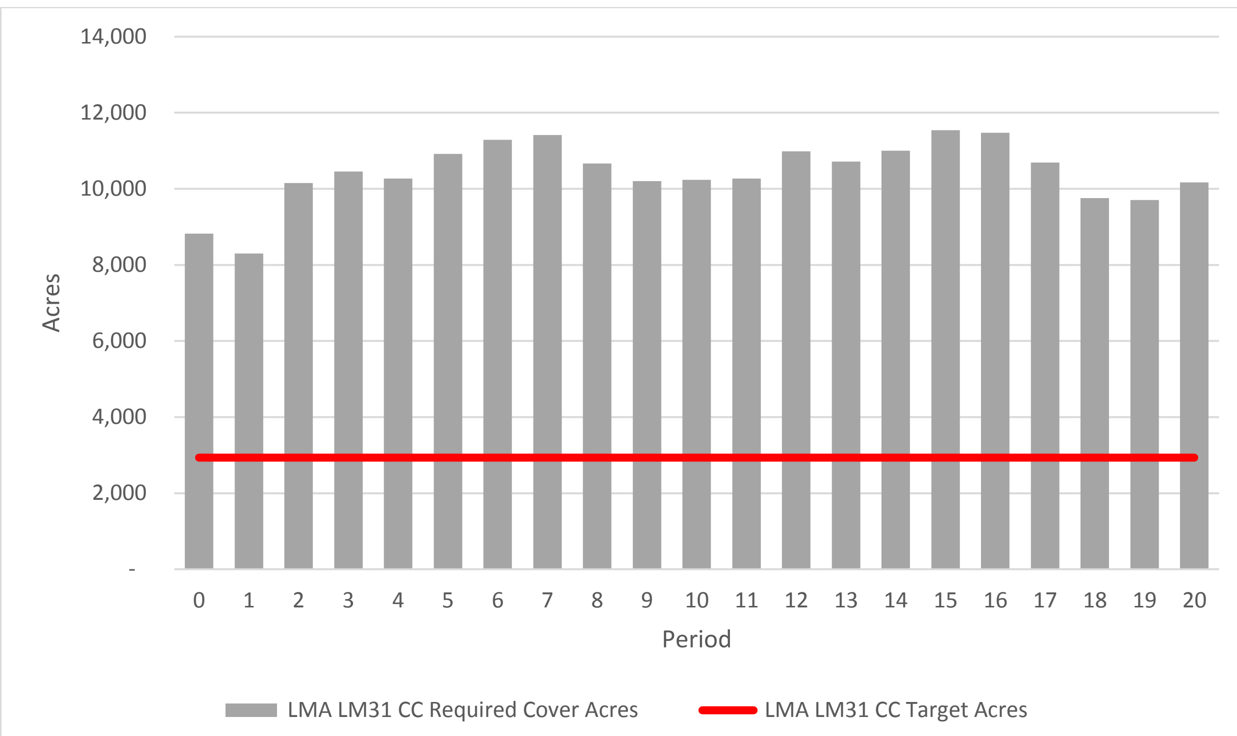


Figure 116: LMA (Coal Creek) Saw-Timber Acres – Grizzly Bear Core Constrained

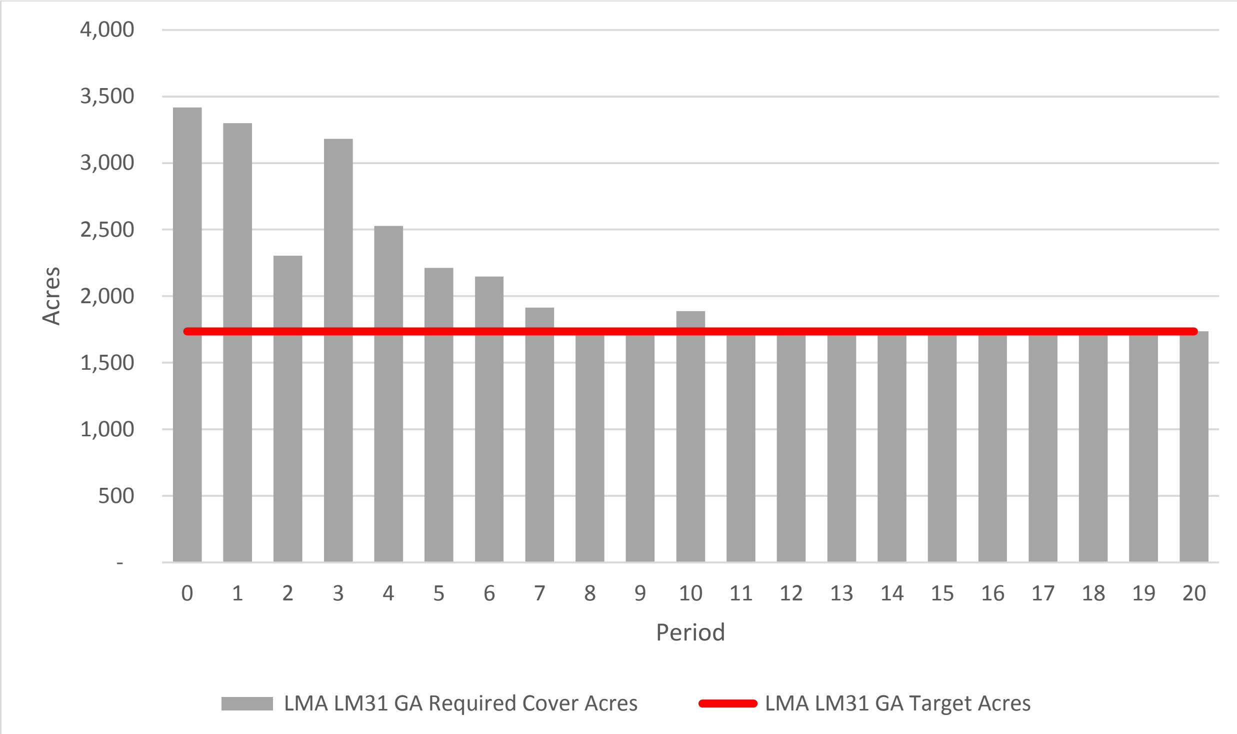


Figure 117: LMA (Garnet) Saw-Timber Acres – Grizzly Bear Core Constrained

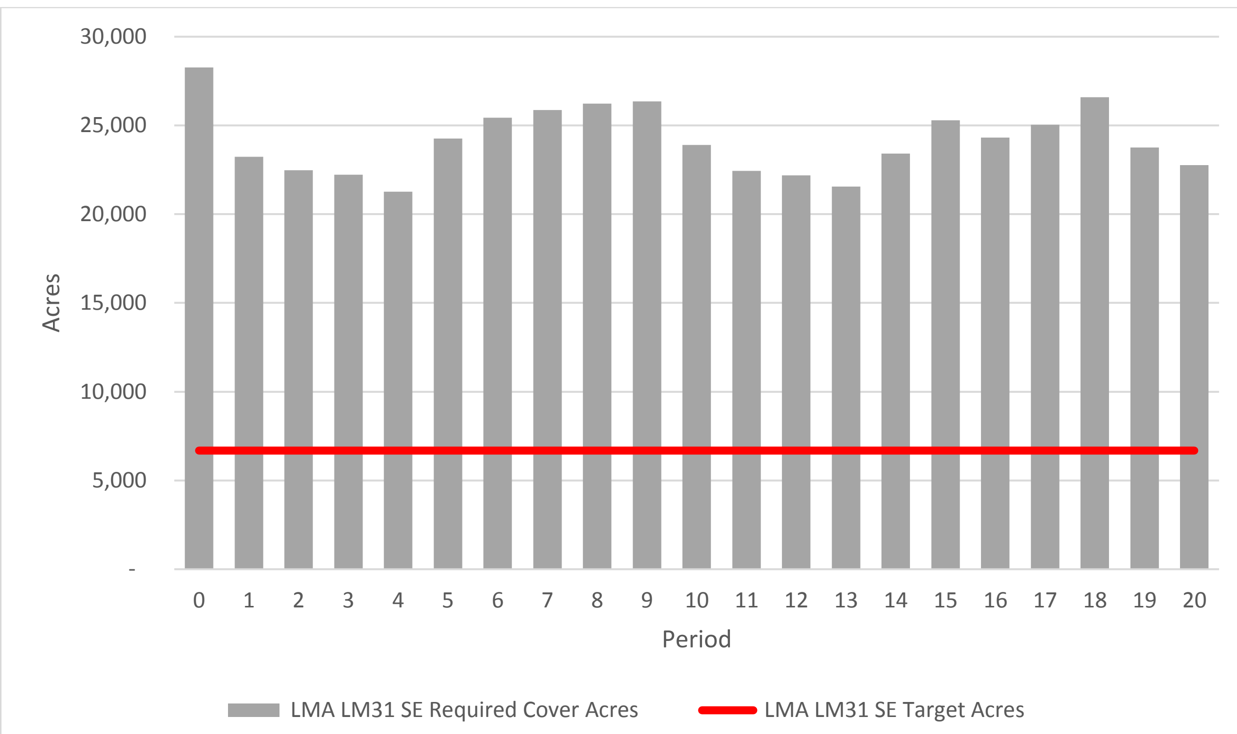


Figure 118: LMA (Stillwater East) Saw-Timber Acres – Grizzly Bear Core Constrained

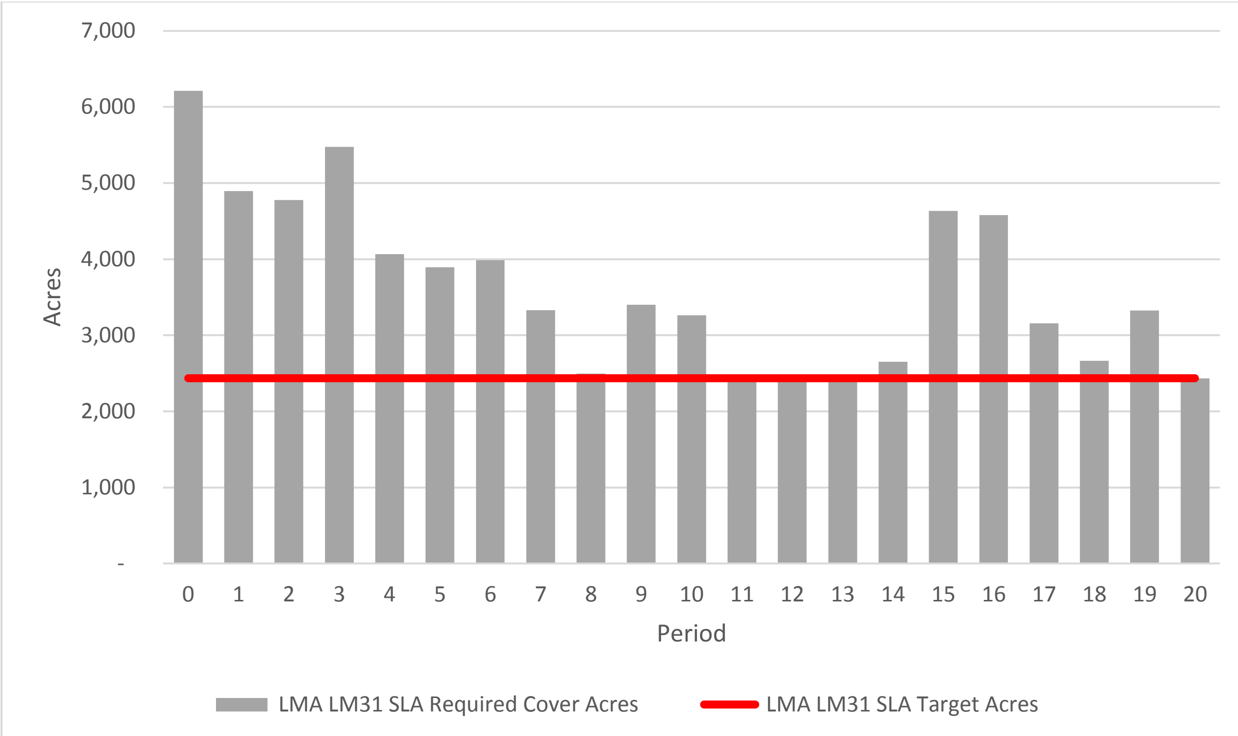


Figure 119: LMA (Seeley Lake) Saw-Timber Acres – Grizzly Bear Core Constrained

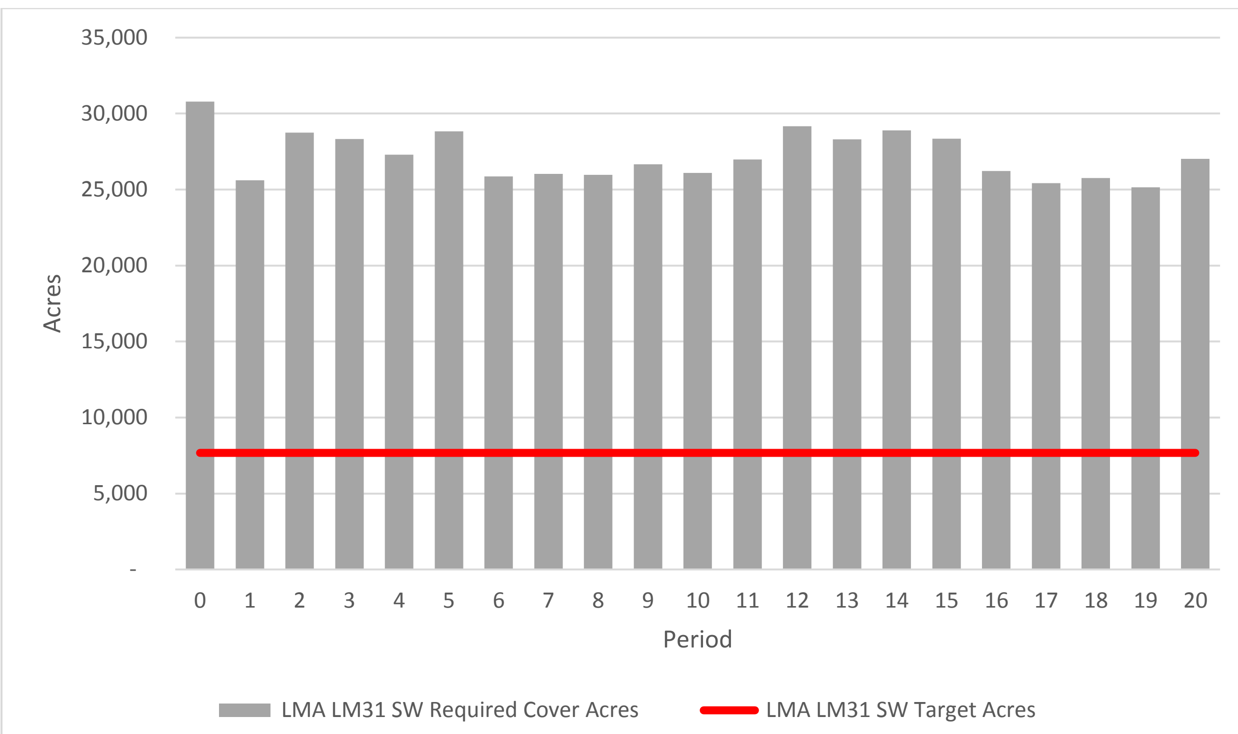


Figure 120: LMA (Stillwater West) Saw-Timber Acres – Grizzly Bear Core Constrained

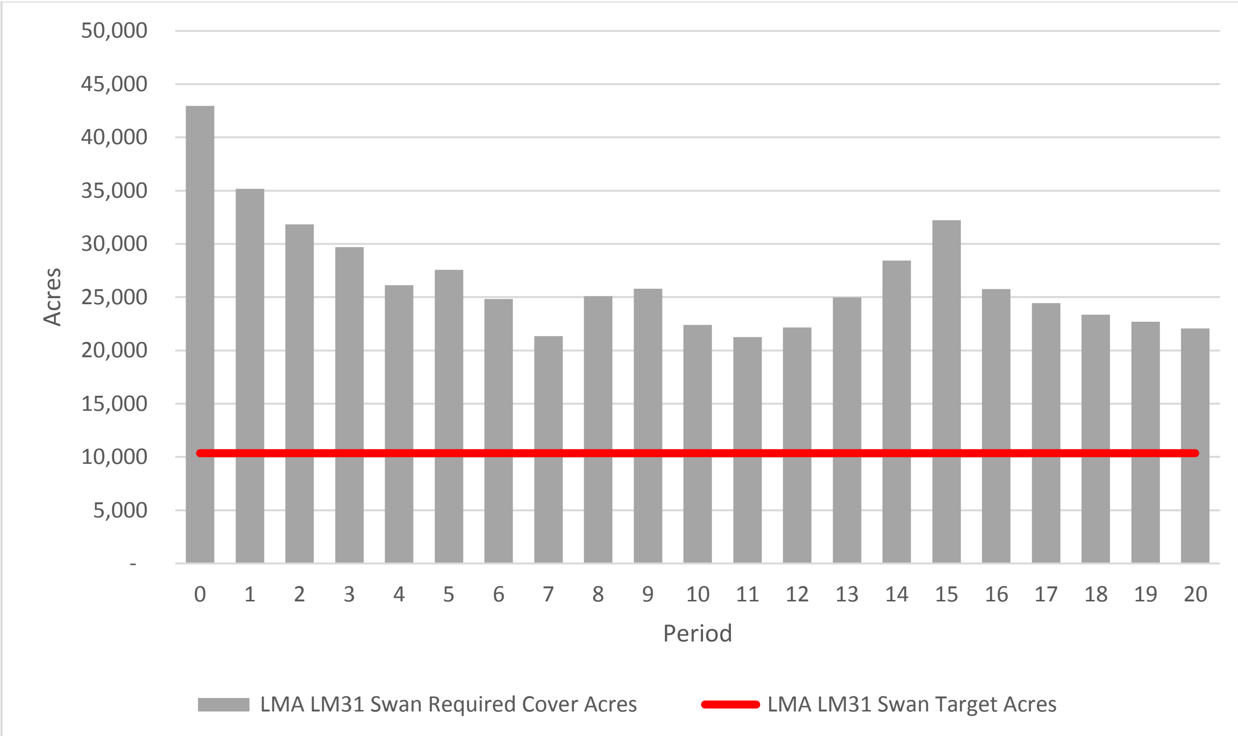


Figure 121: LMA (Swan) Saw-Timber Acres – Grizzly Bear Core Constrained

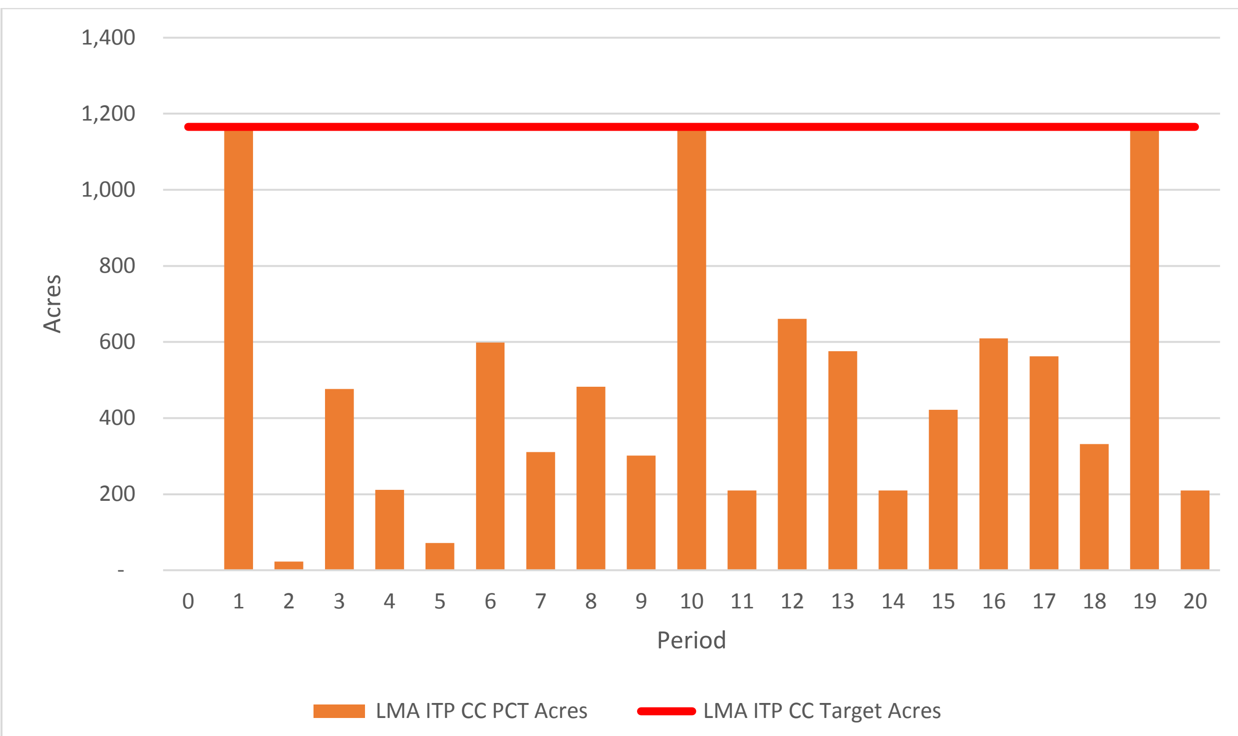


Figure 122: LMA (Coal Creek) PCT Acres – Grizzly Bear Core Constrained

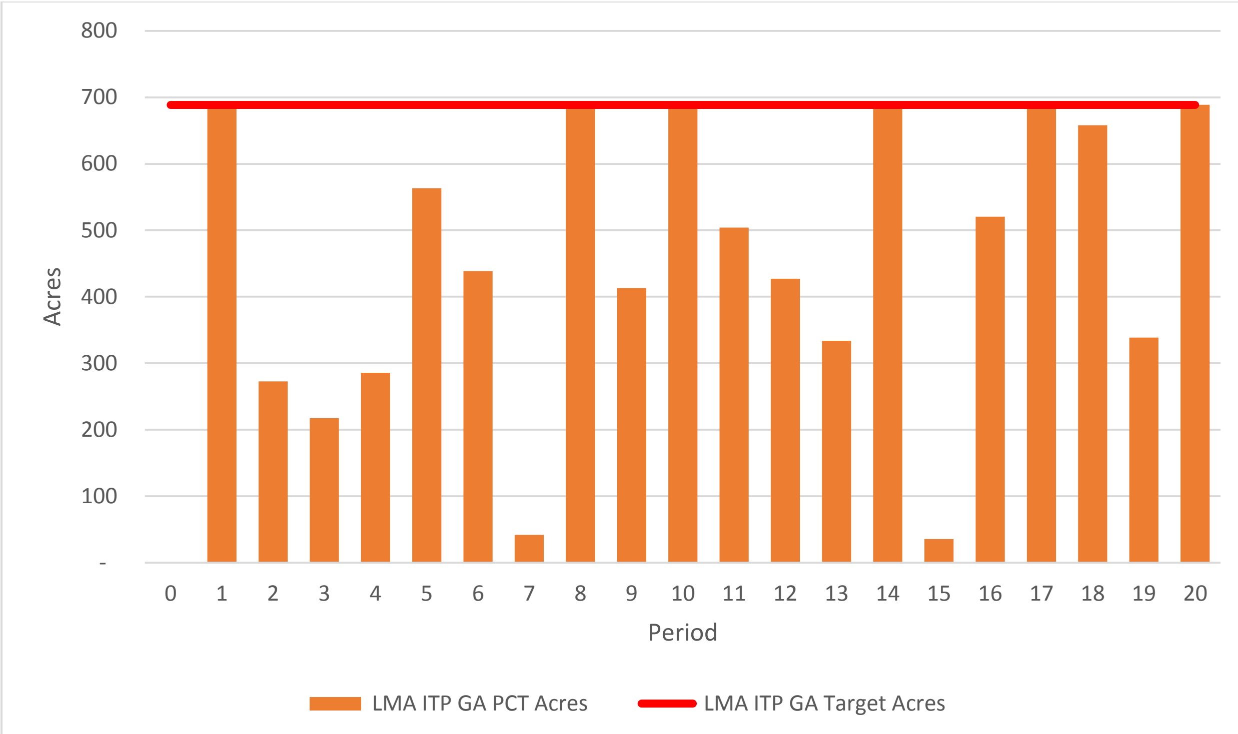


Figure 123: LMA (Garnet) PCT Acres – Grizzly Bear Core Constrained

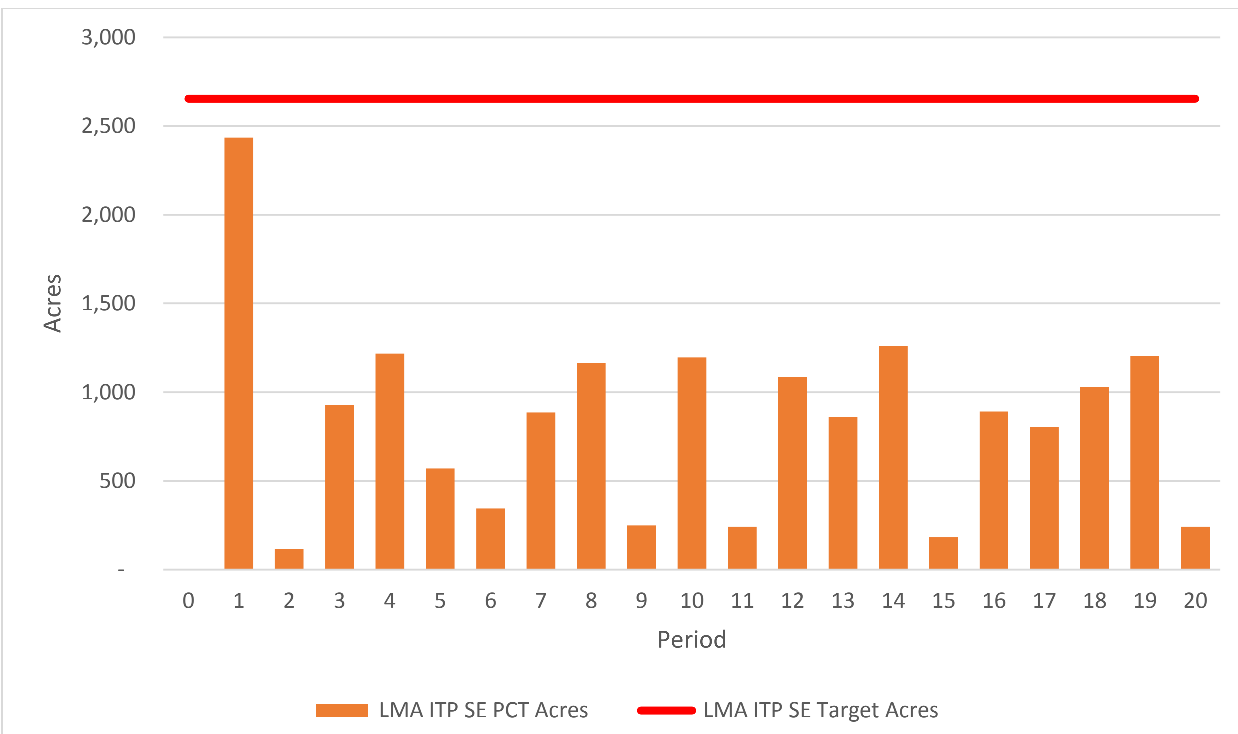


Figure 124: LMA (Stillwater East) PCT Acres – Grizzly Bear Core Constrained

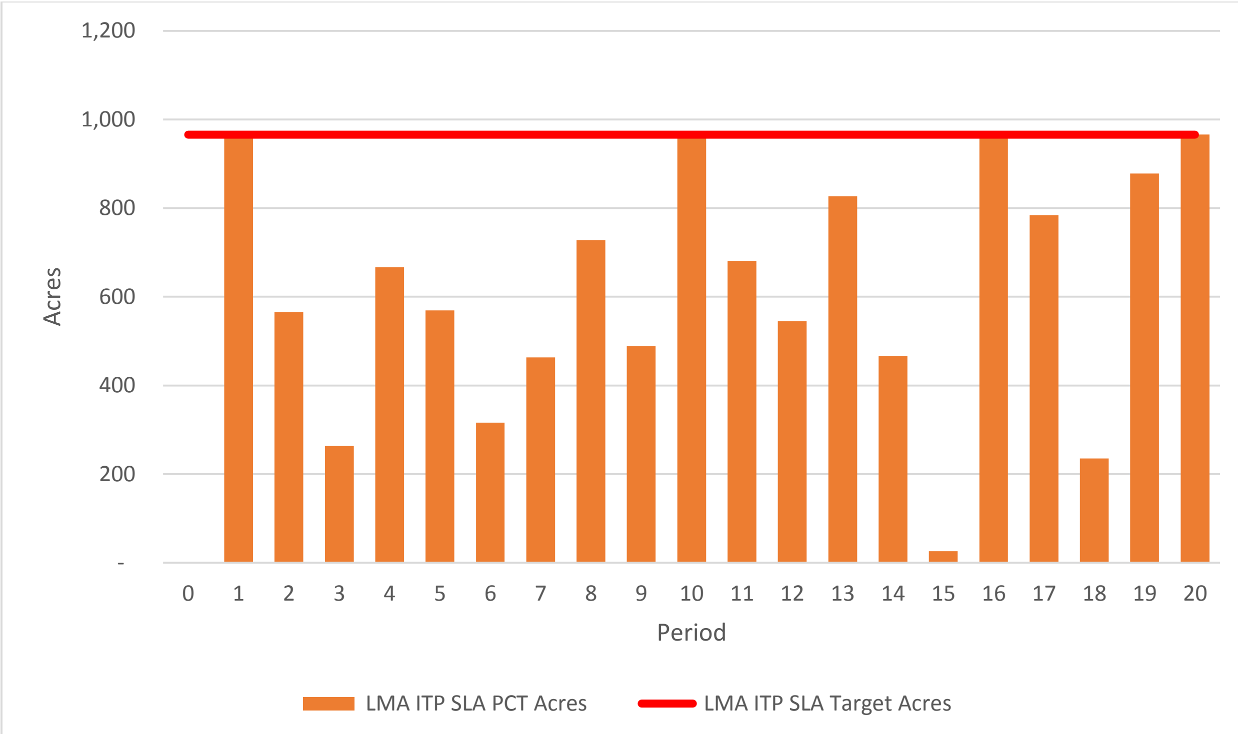


Figure 125: LMA (Seeley Lake) PCT Acres – Grizzly Bear Core Constrained

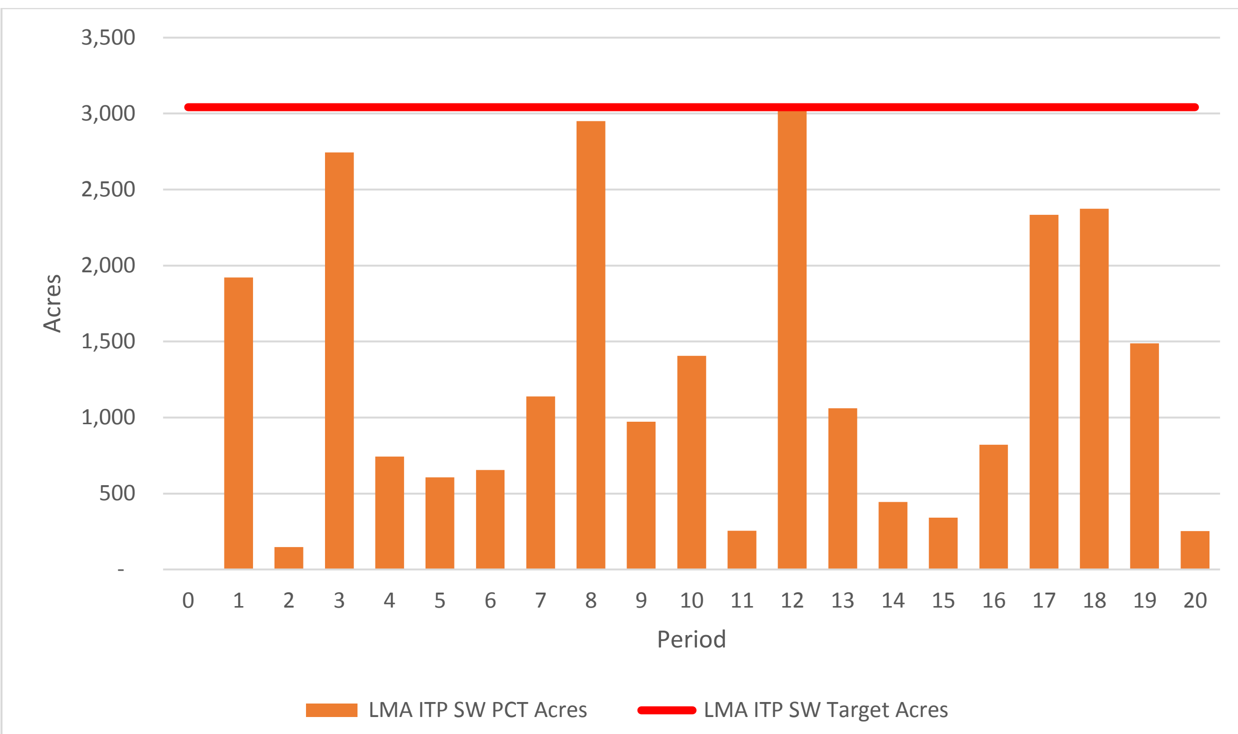


Figure 126: LMA (Stillwater West) PCT Acres – Grizzly Bear Core Constrained

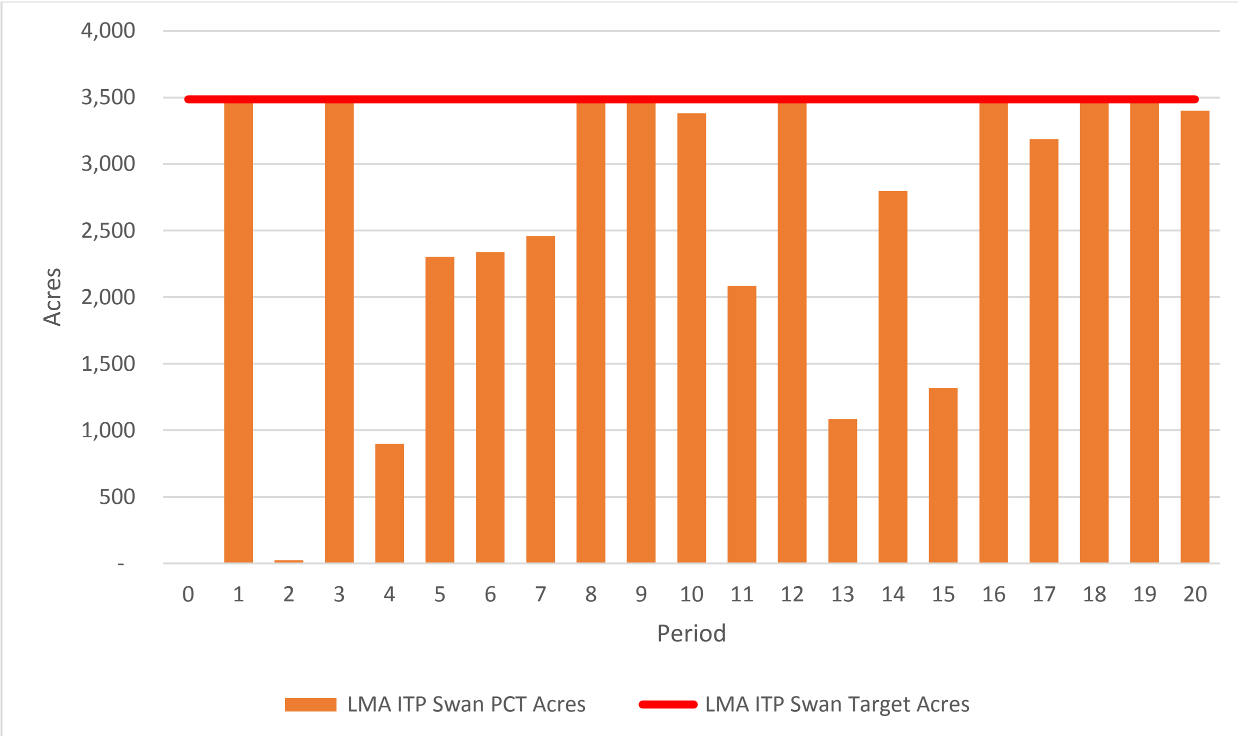


Figure 127: LMA (Swan) PCT Acres – Grizzly Bear Core Constrained

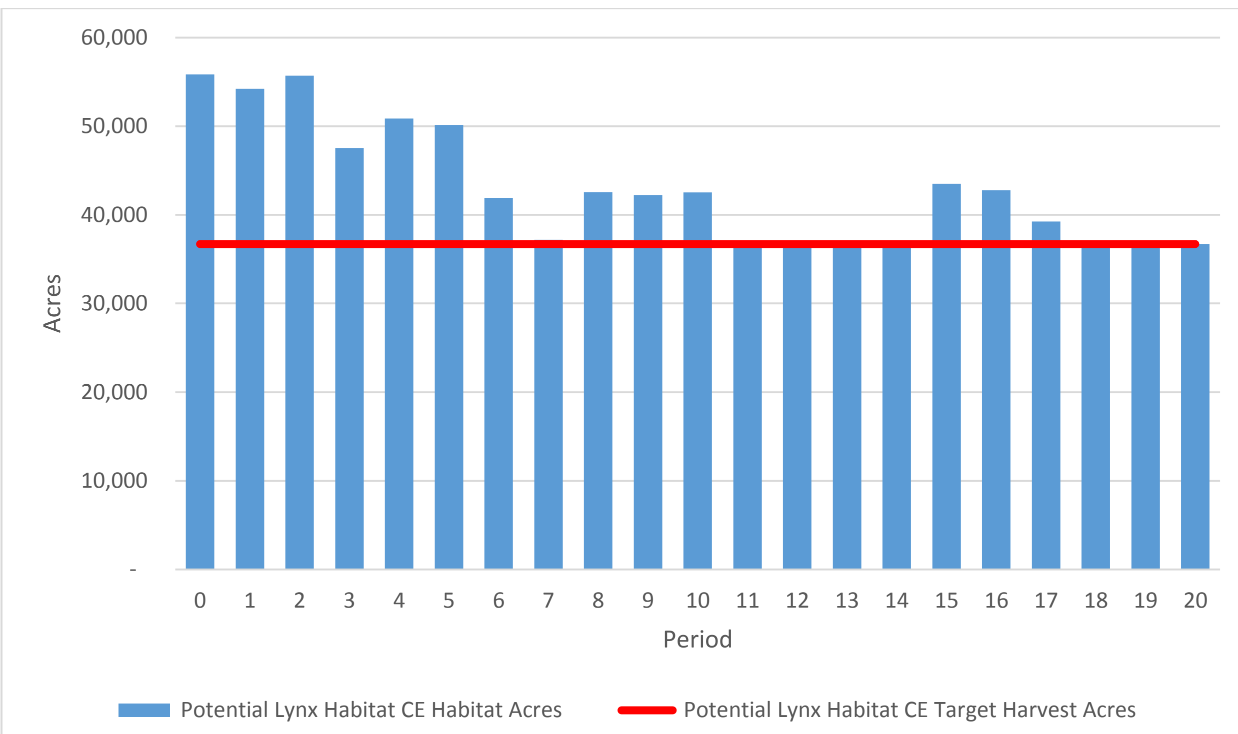


Figure 128: Potential Lynx Habitat Development (CE) – Grizzly Bear Core Constrained

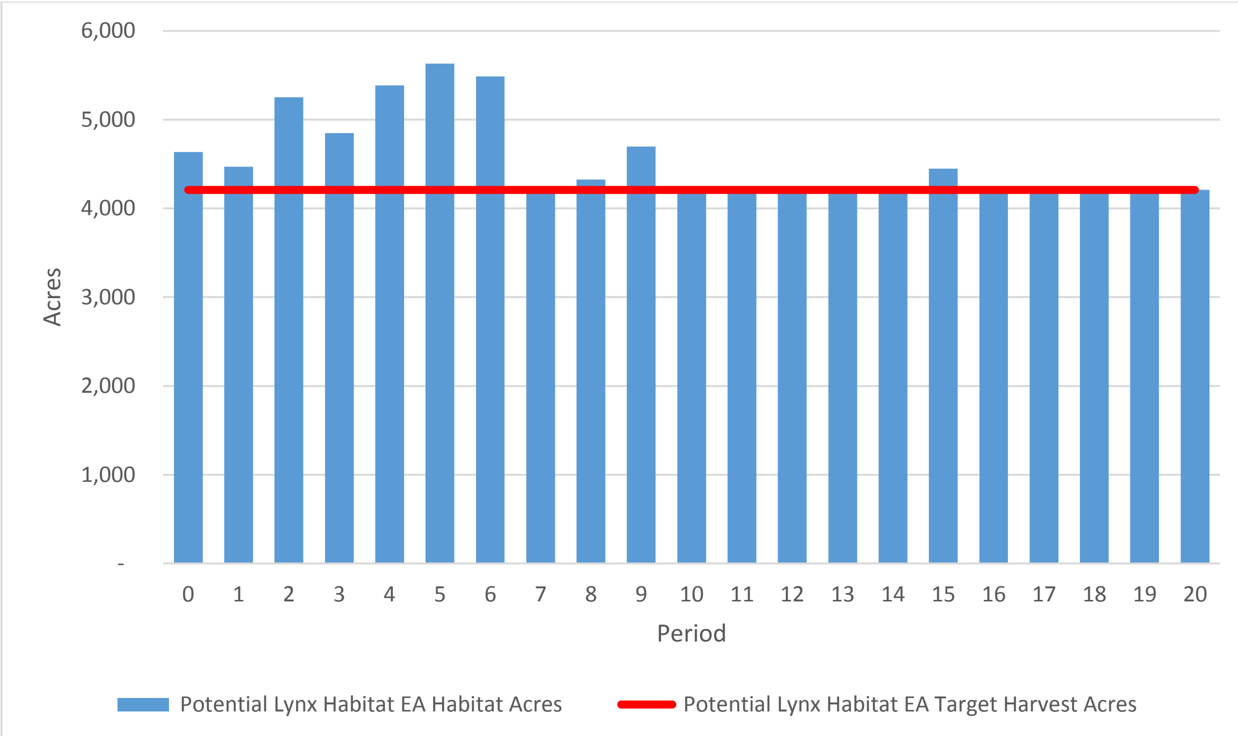


Figure 129: Potential Lynx Habitat Development (EA) – Grizzly Bear Core Constrained

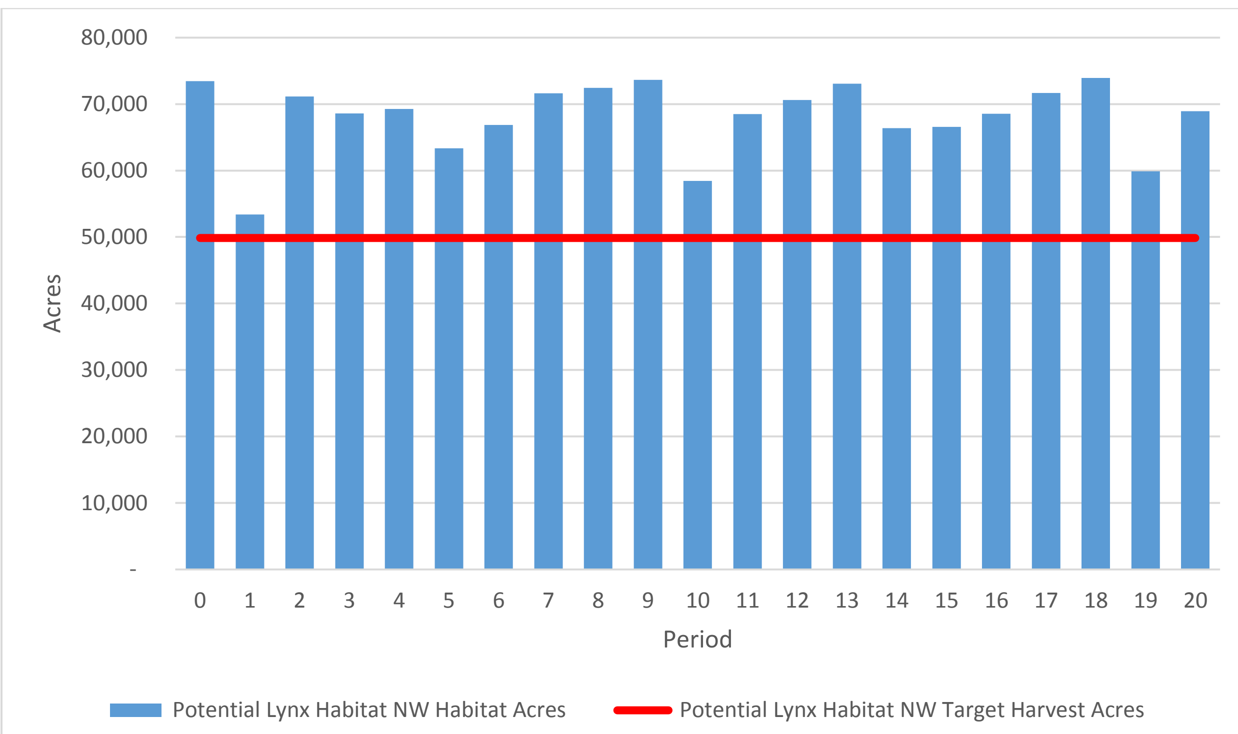


Figure 130: Potential Lynx Habitat Development (NW) – Grizzly Bear Core Constrained

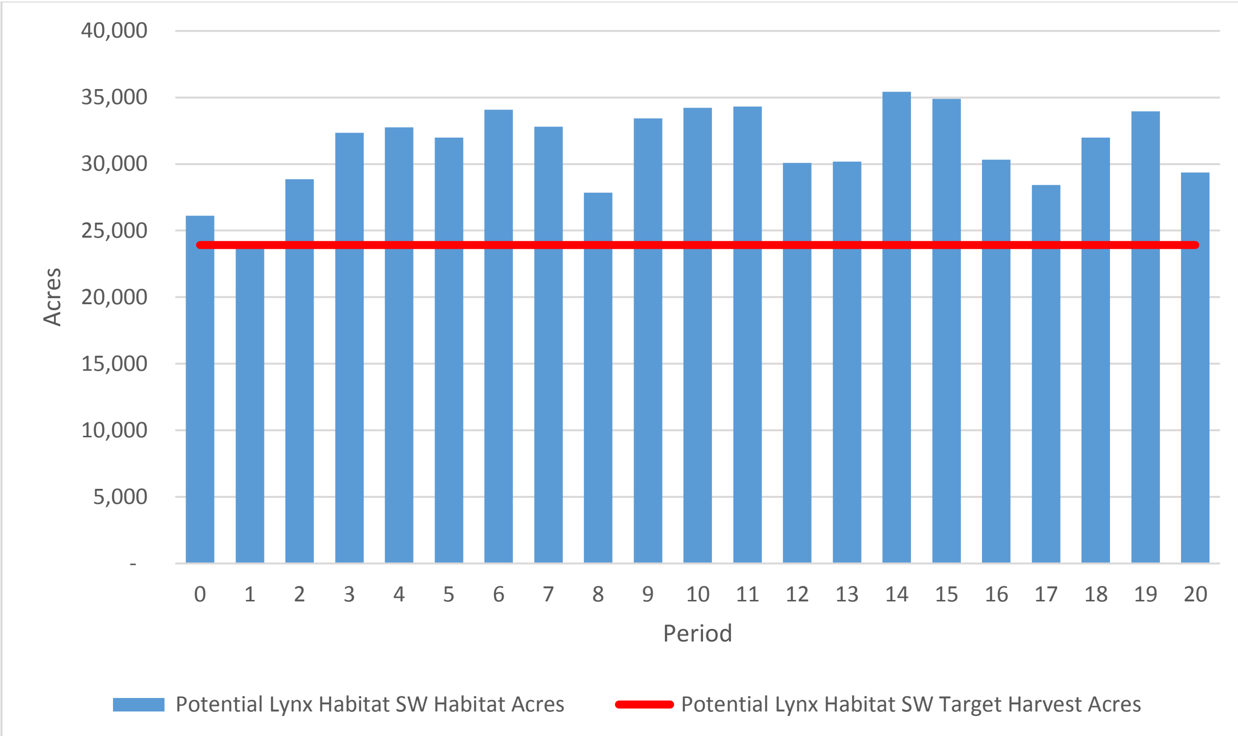


Figure 131: Potential Lynx Habitat Development (SW) – Grizzly Bear Core Constrained

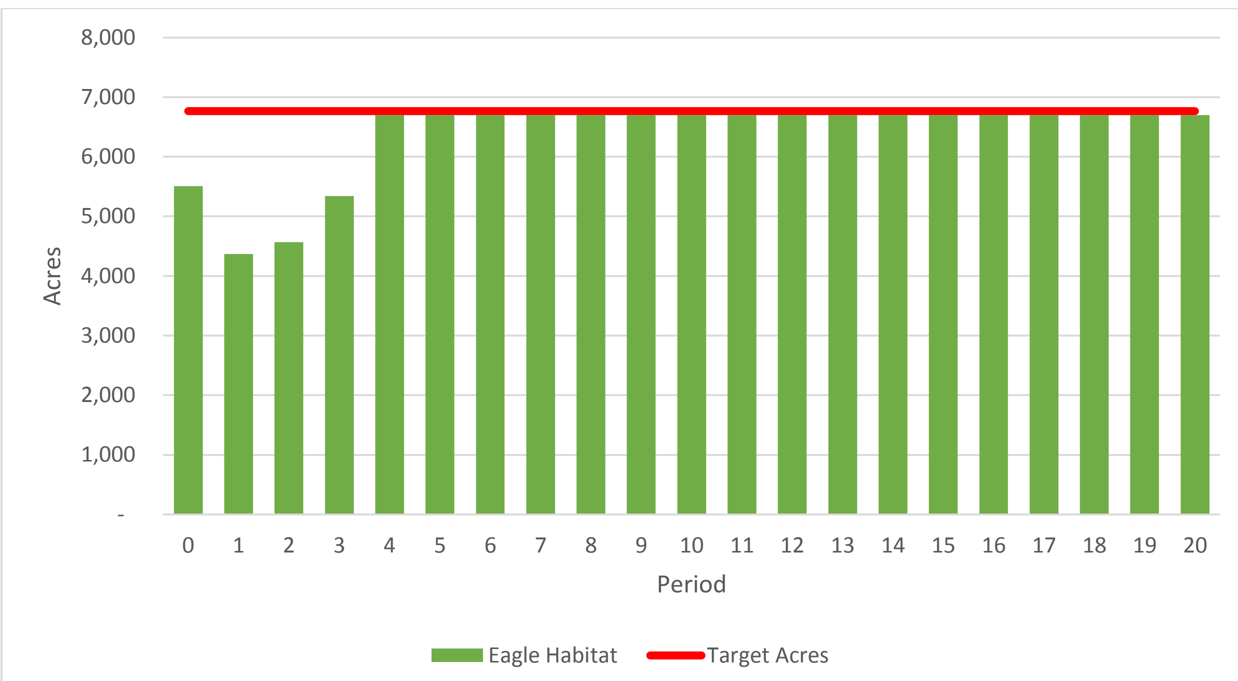


Figure 132: Bald Eagle Habitat Acres – Grizzly Bear Core Constrained

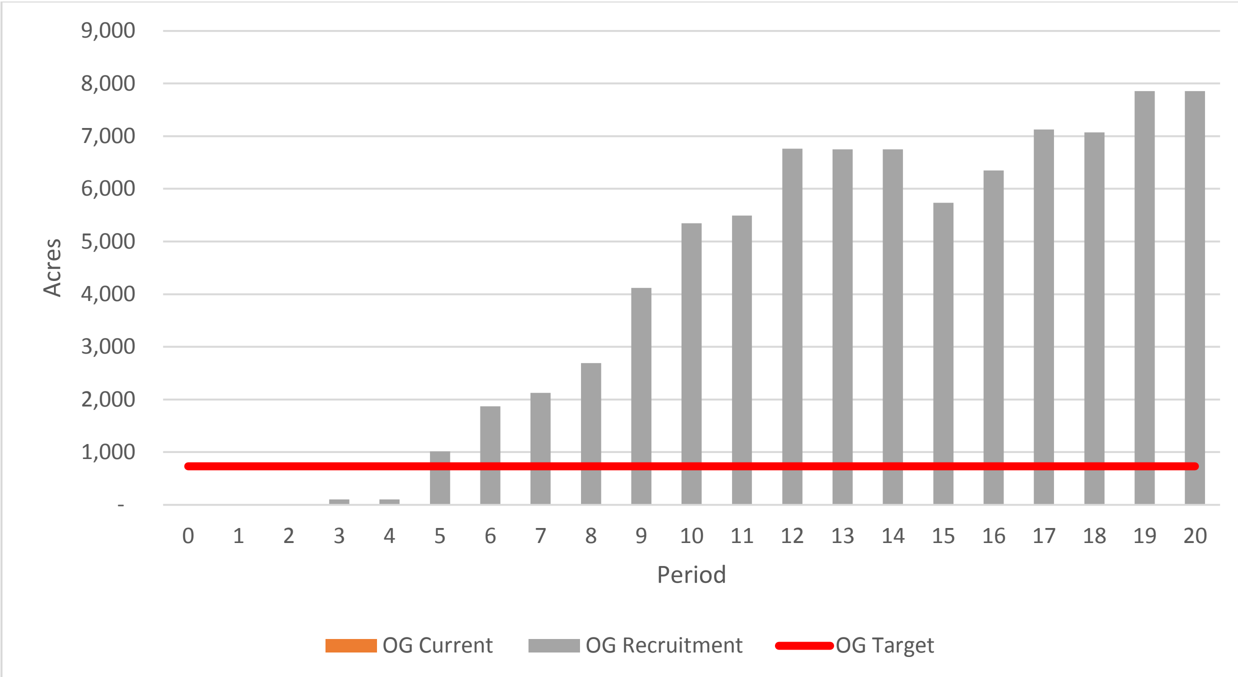


Figure 133: CE Old Growth Acres (Bozeman) – Grizzly Bear Core Constrained

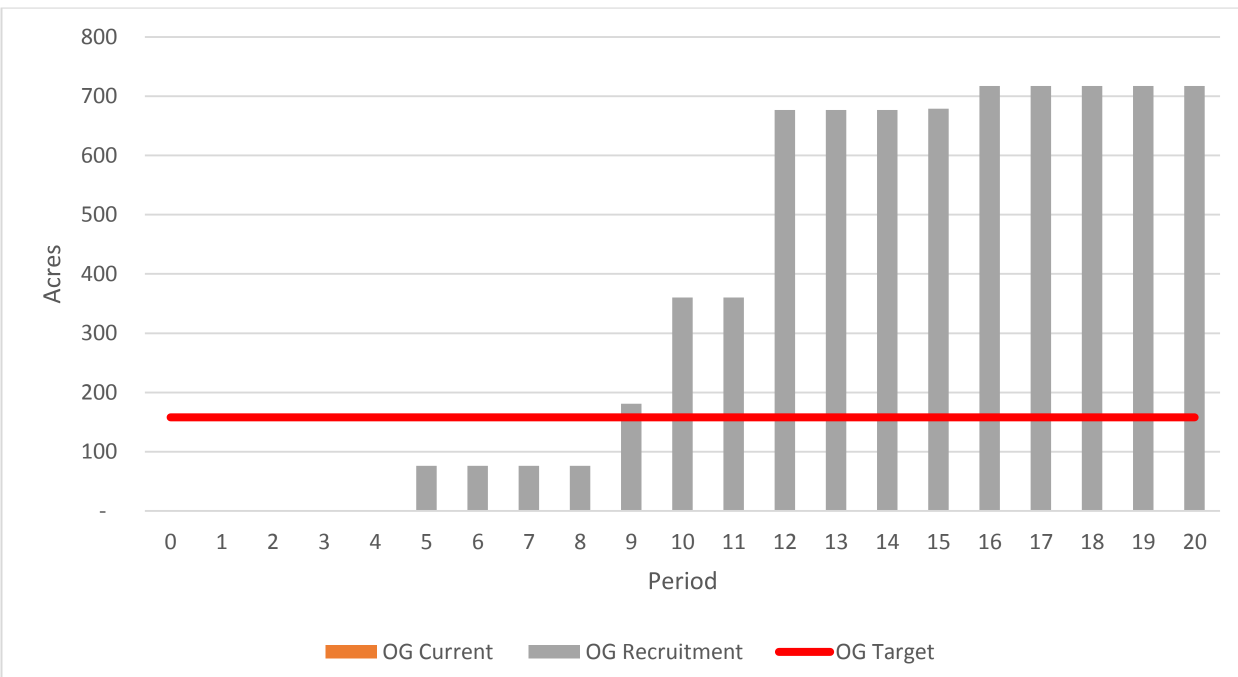


Figure 134: CE Old Growth Acres (Conrad) – Grizzly Bear Core Constrained

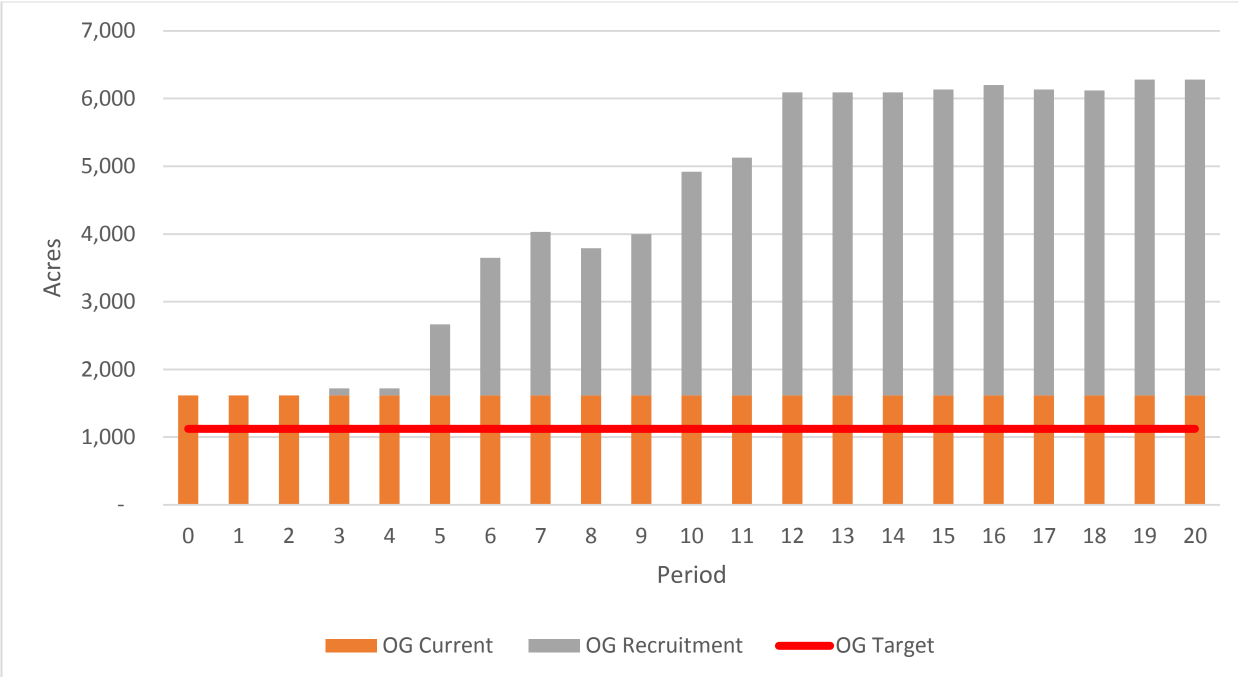


Figure 135: CE Old Growth Acres (Dillon) – Grizzly Bear Core Constrained

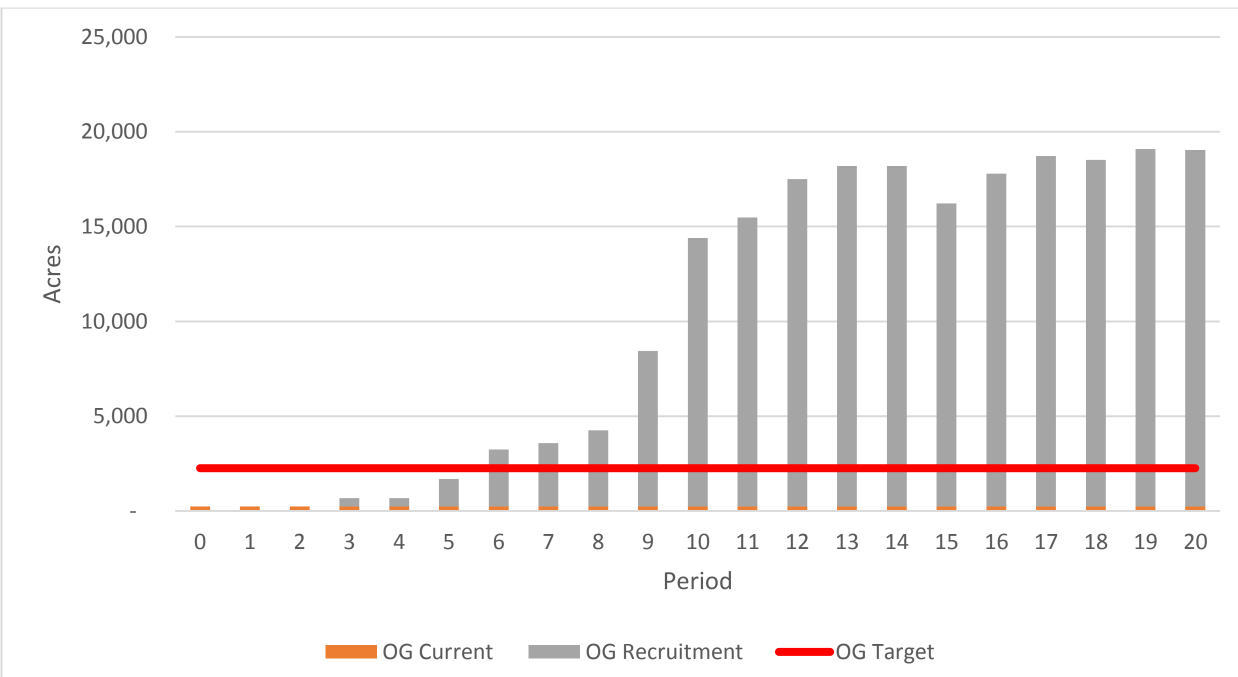


Figure 136: CE Old Growth Acres (Helena) – Grizzly Bear Core Constrained

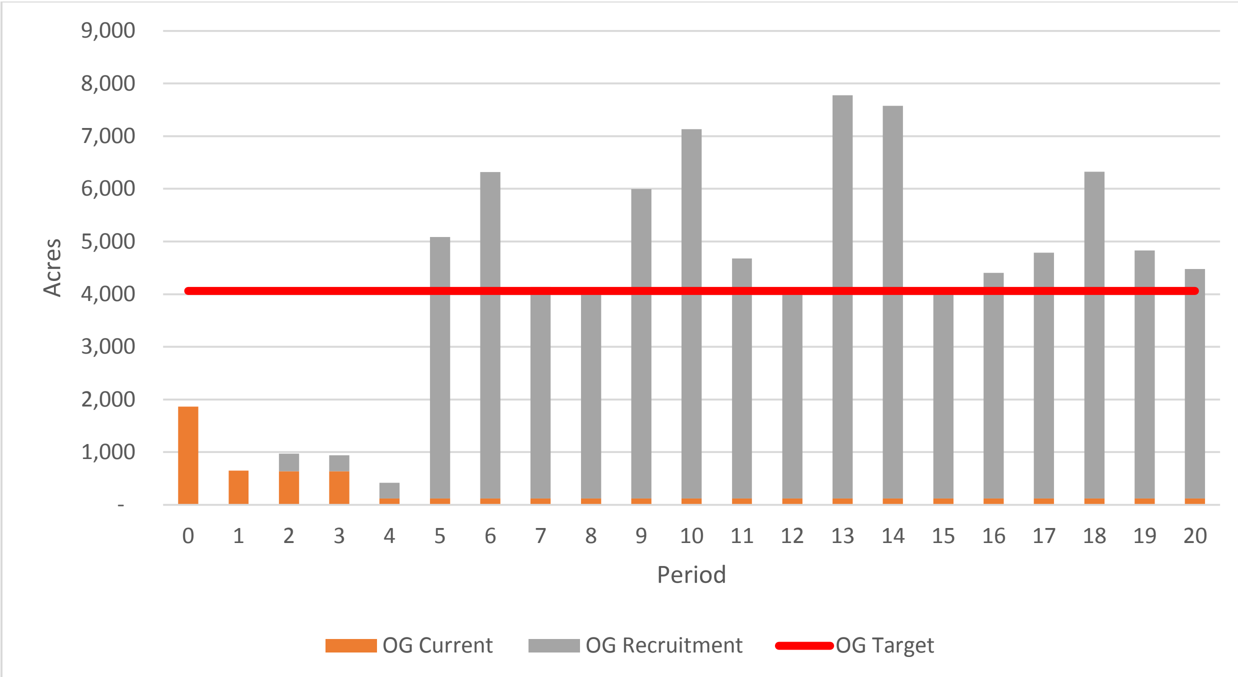


Figure 137: NW Old Growth Acres (Kalispell) – Grizzly Bear Core Constrained

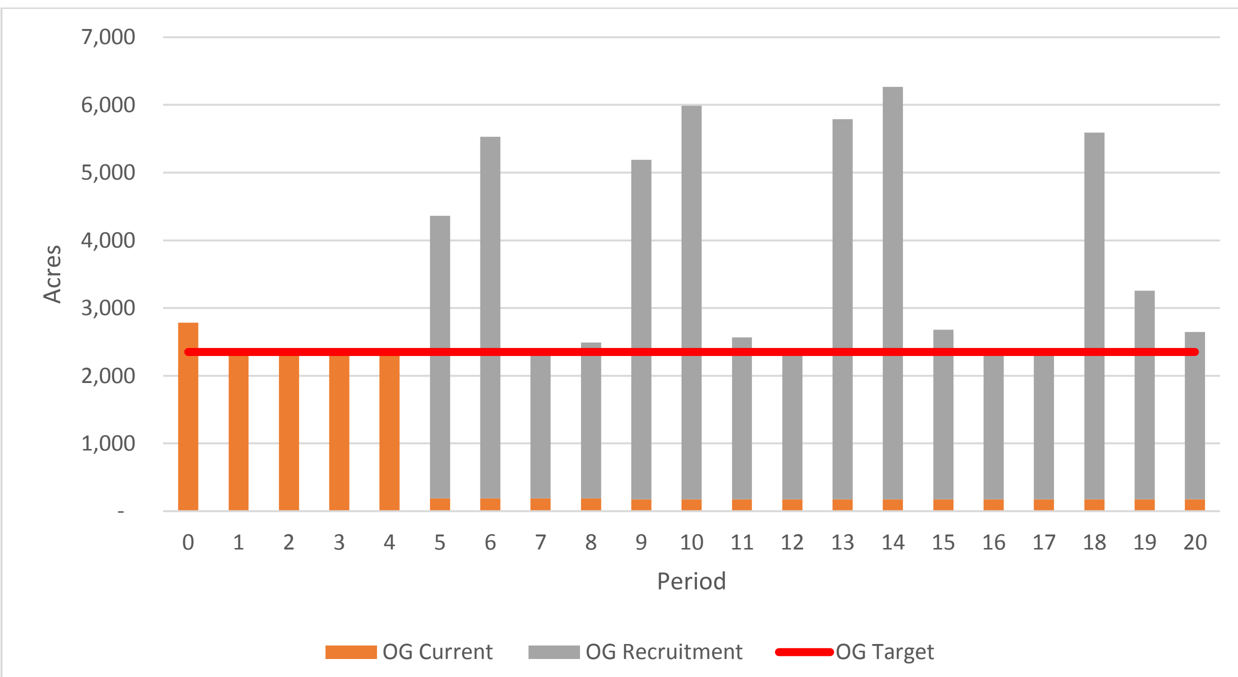


Figure 138: NW Old Growth Acres (Libby) – Grizzly Bear Core Constrained

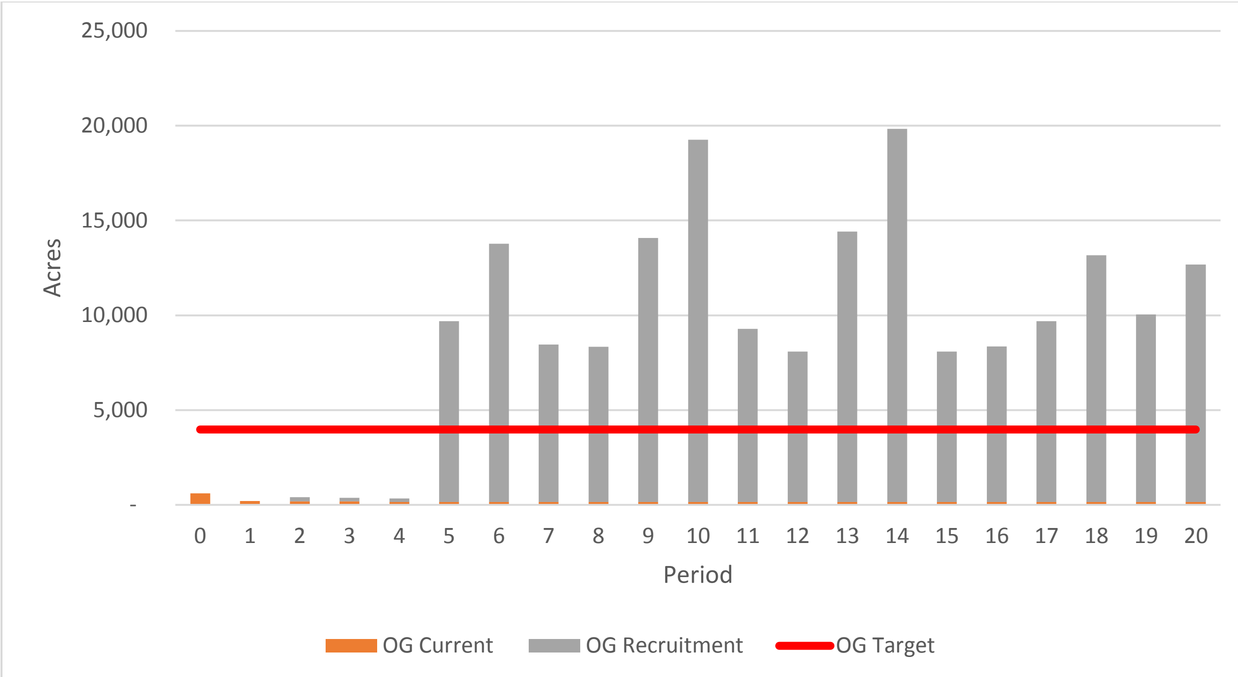


Figure 139: NW Old Growth Acres (Plains) – Grizzly Bear Core Constrained

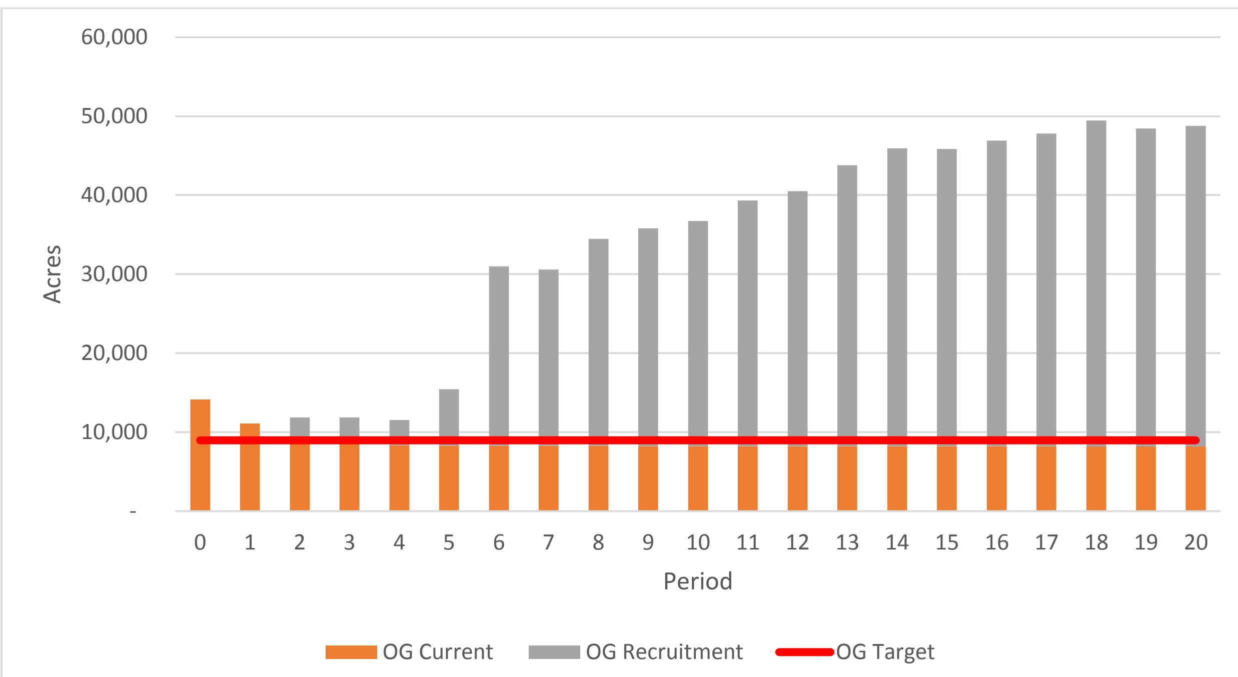


Figure 140: NW Old Growth Acres (Stillwater) – Grizzly Bear Core Constrained

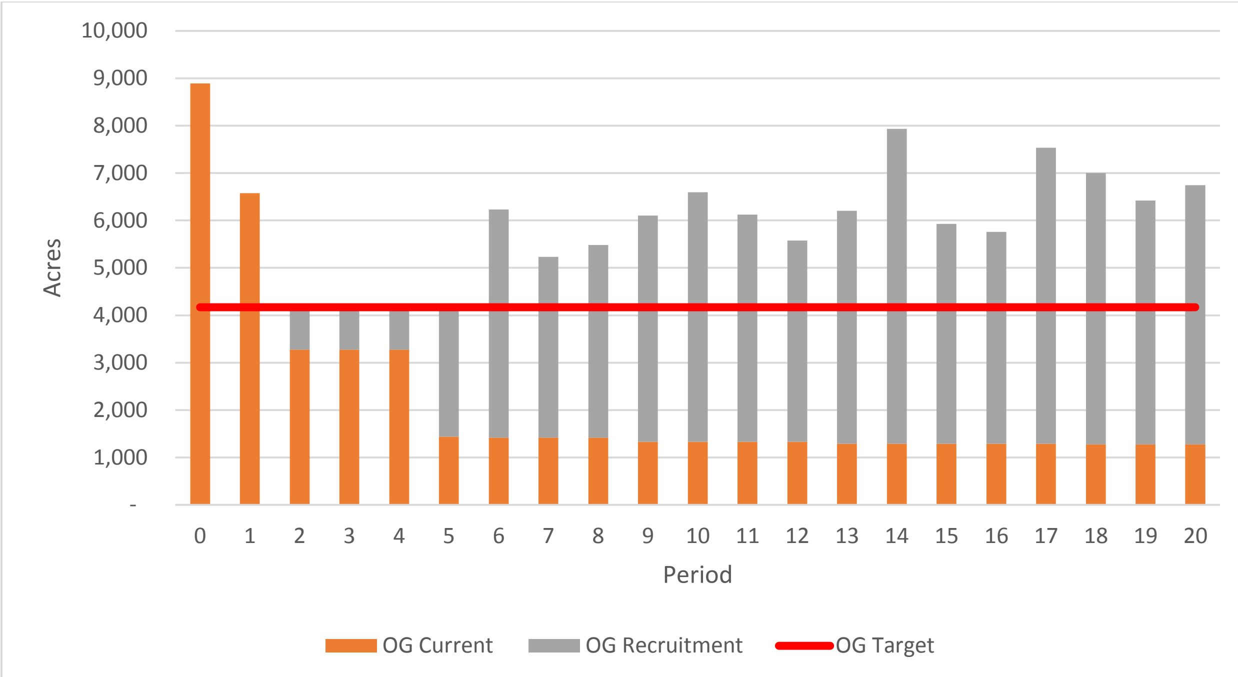


Figure 141: NW Old Growth Acres (Swan) – Grizzly Bear Core Constrained

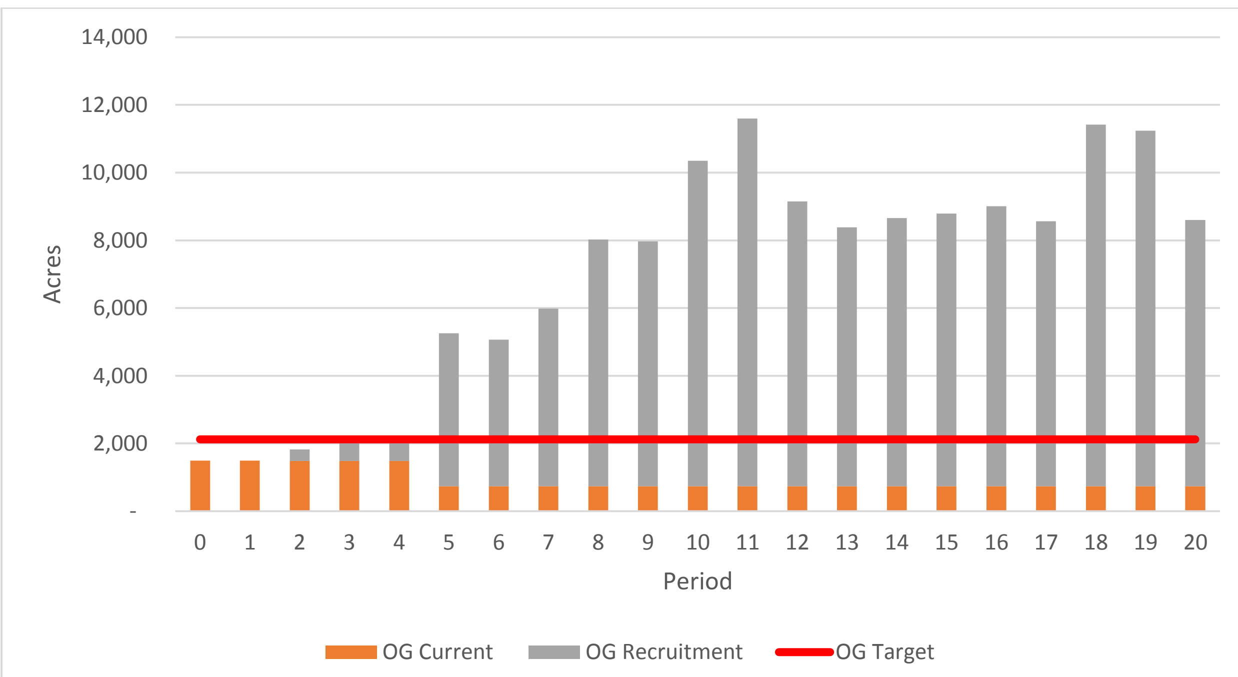


Figure 142: SW Old Growth Acres (Anaconda) – Grizzly Bear Core Constrained

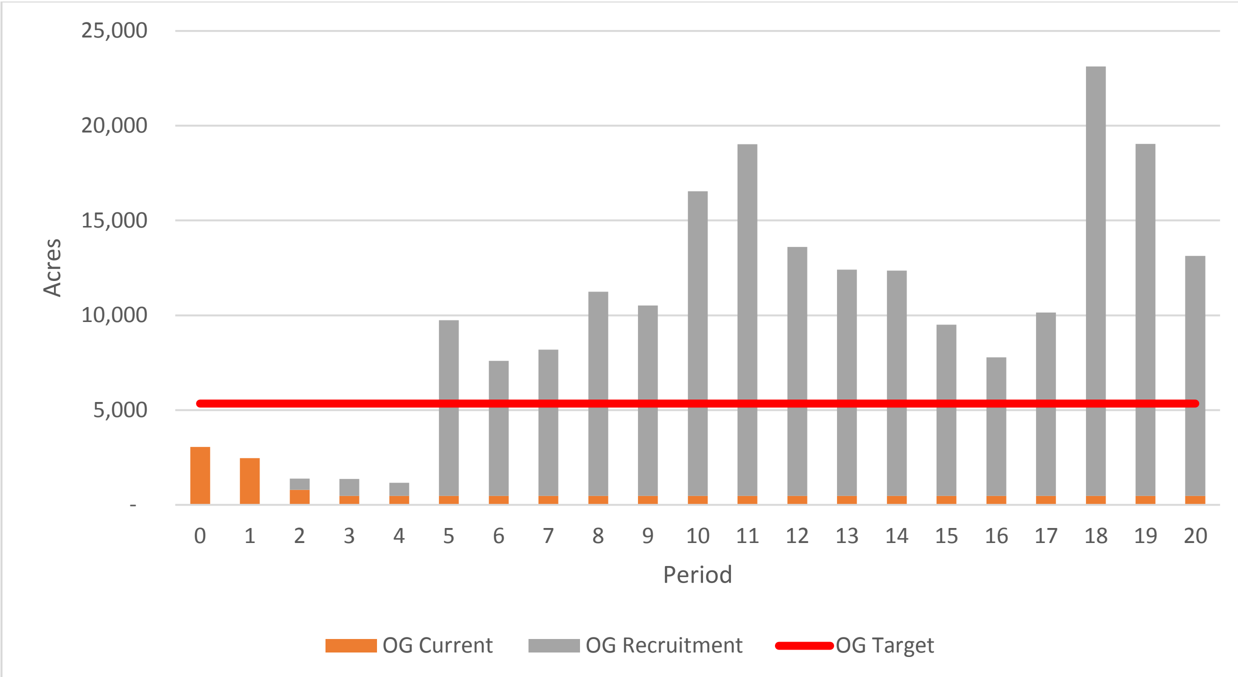


Figure 143: SW Old Growth Acres (Clearwater) – Grizzly Bear Core Constrained

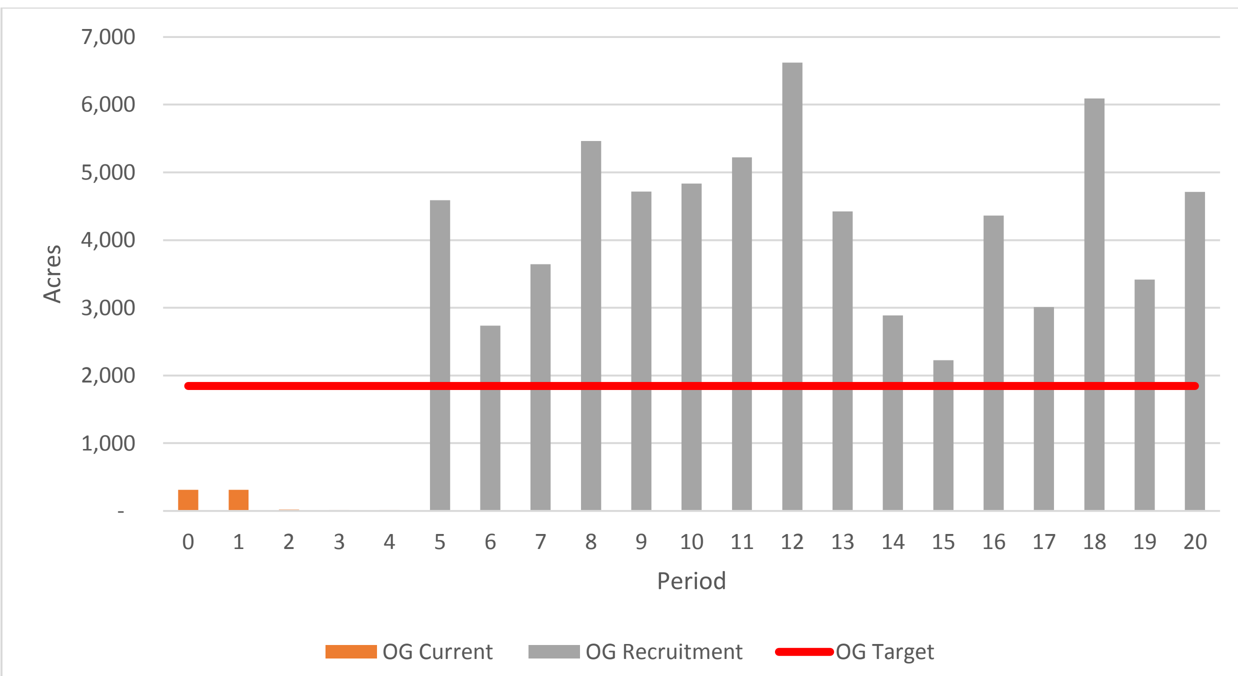


Figure 144: SW Old Growth Acres (Hamilton) – Grizzly Bear Core Constrained

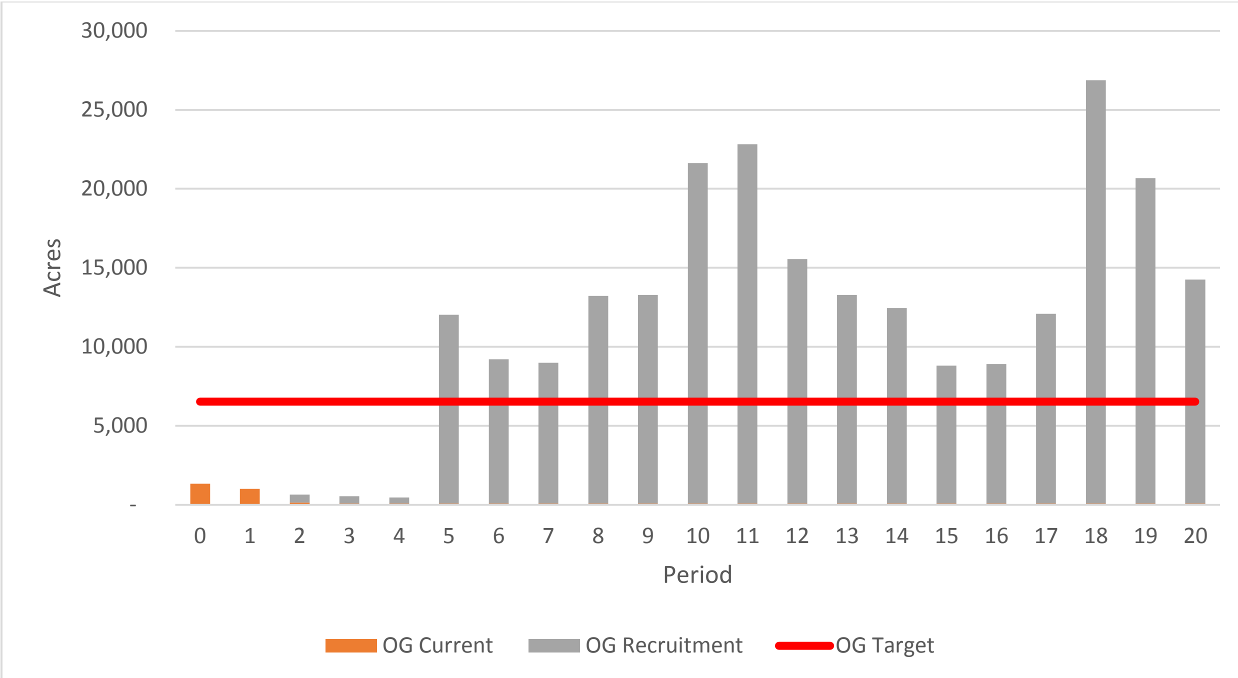


Figure 145: SW Old Growth Acres (Missoula) – Grizzly Bear Core Constrained

20.3 Constrained Grizzly Bear Security Zones Acres

The following charts show selected results from the final LP model run with constrained Grizzly Bear Security Zone acres (active management not allowed within the Security Zones).

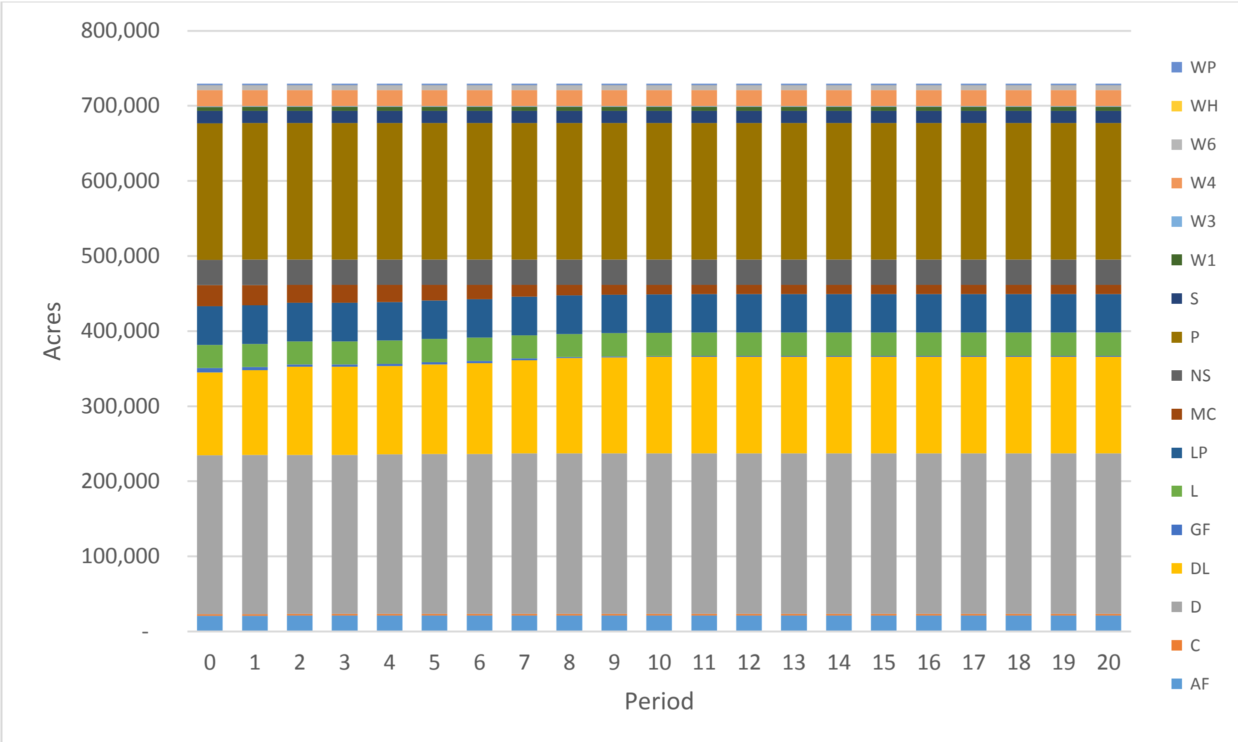


Figure 146: Acres by Species – Grizzly Bear Security Zones Constrained

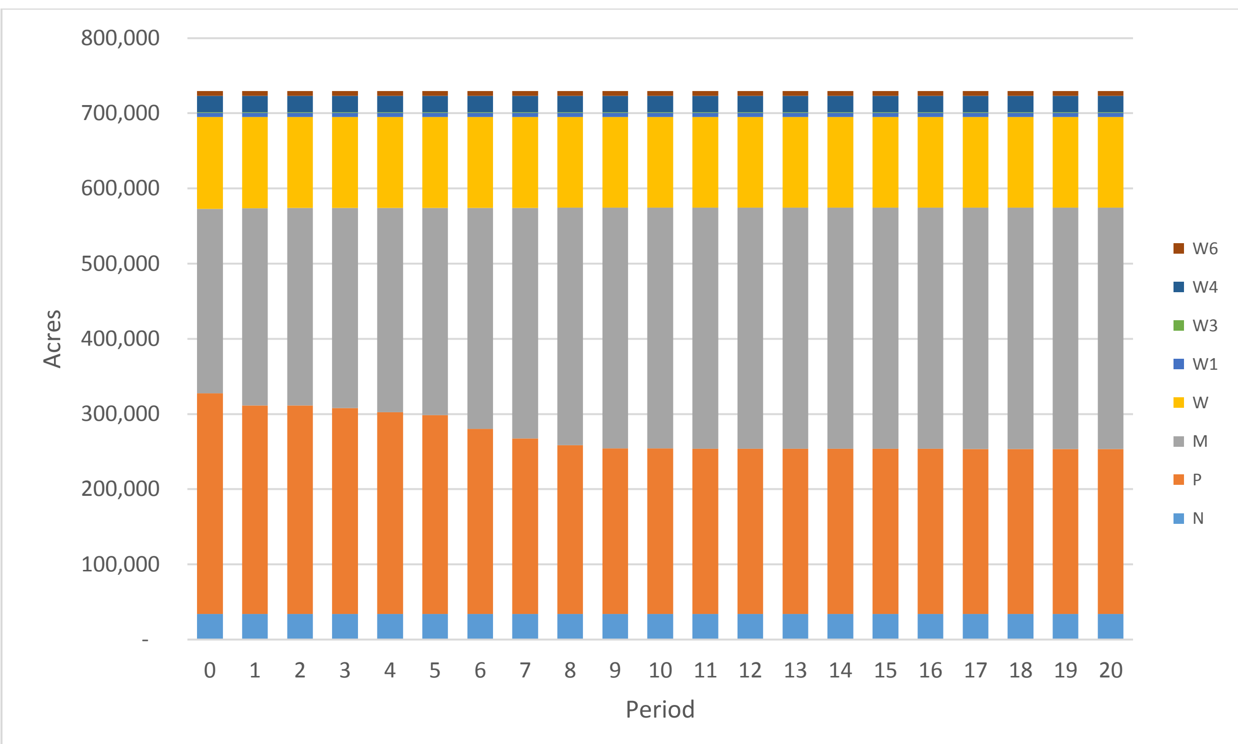


Figure 147: Acres by Stocking – Grizzly Bear Security Zones Constrained

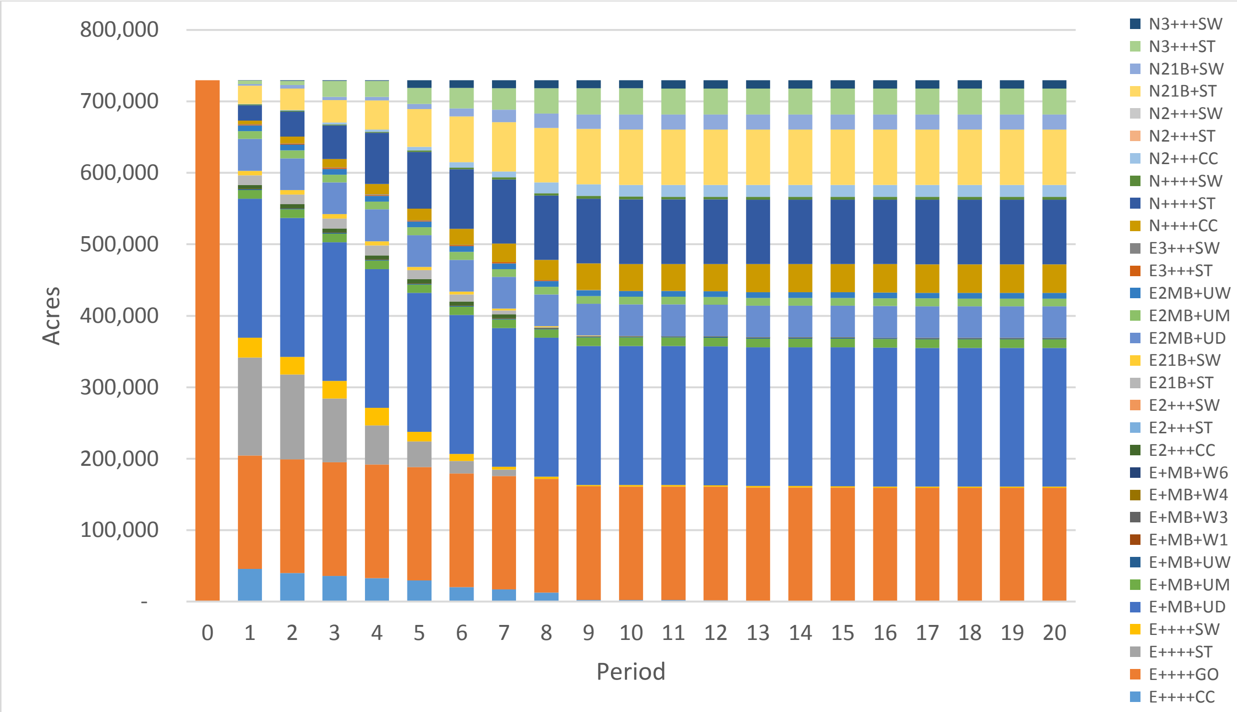


Figure 148: Management Pathway Acres – Grizzly Bear Security Zones Constrained

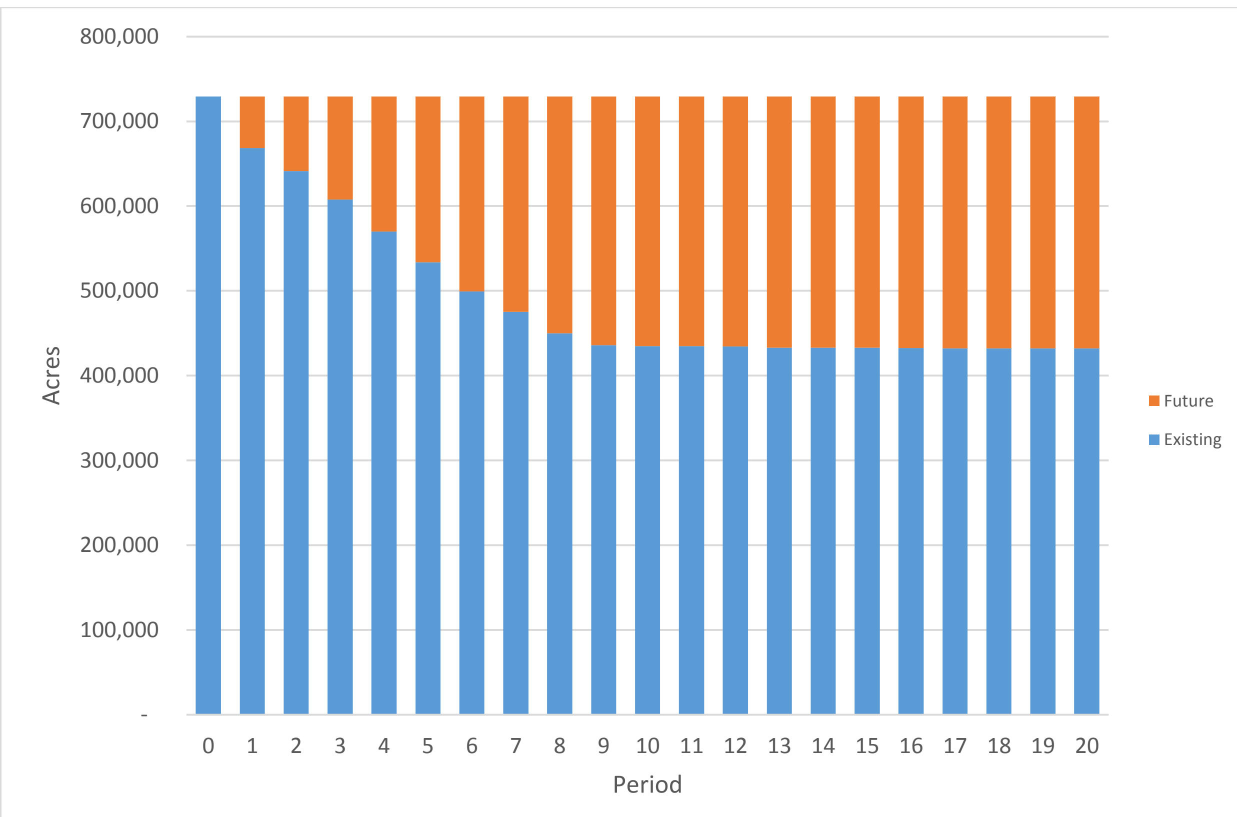


Figure 149: Existing vs. Future Rotation Acres – Grizzly Bear Security Zones Constrained

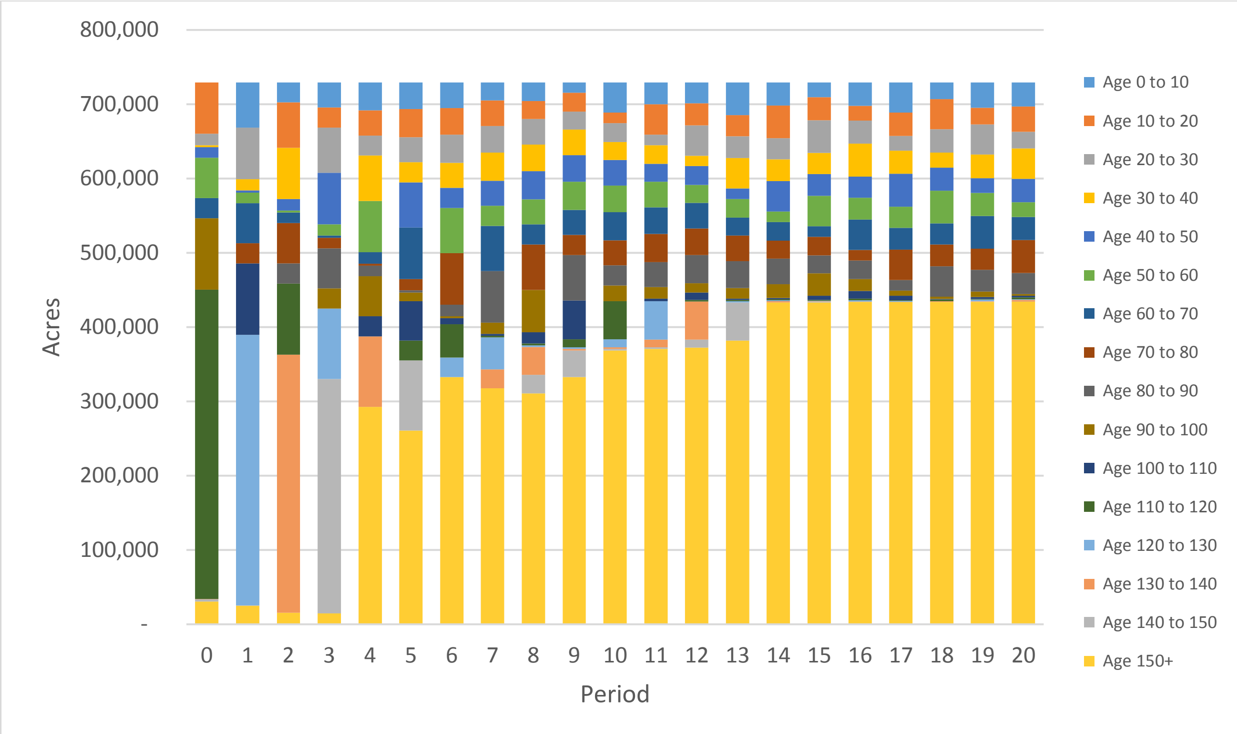


Figure 150: Age Class Distribution – Grizzly Bear Security Zones Constrained

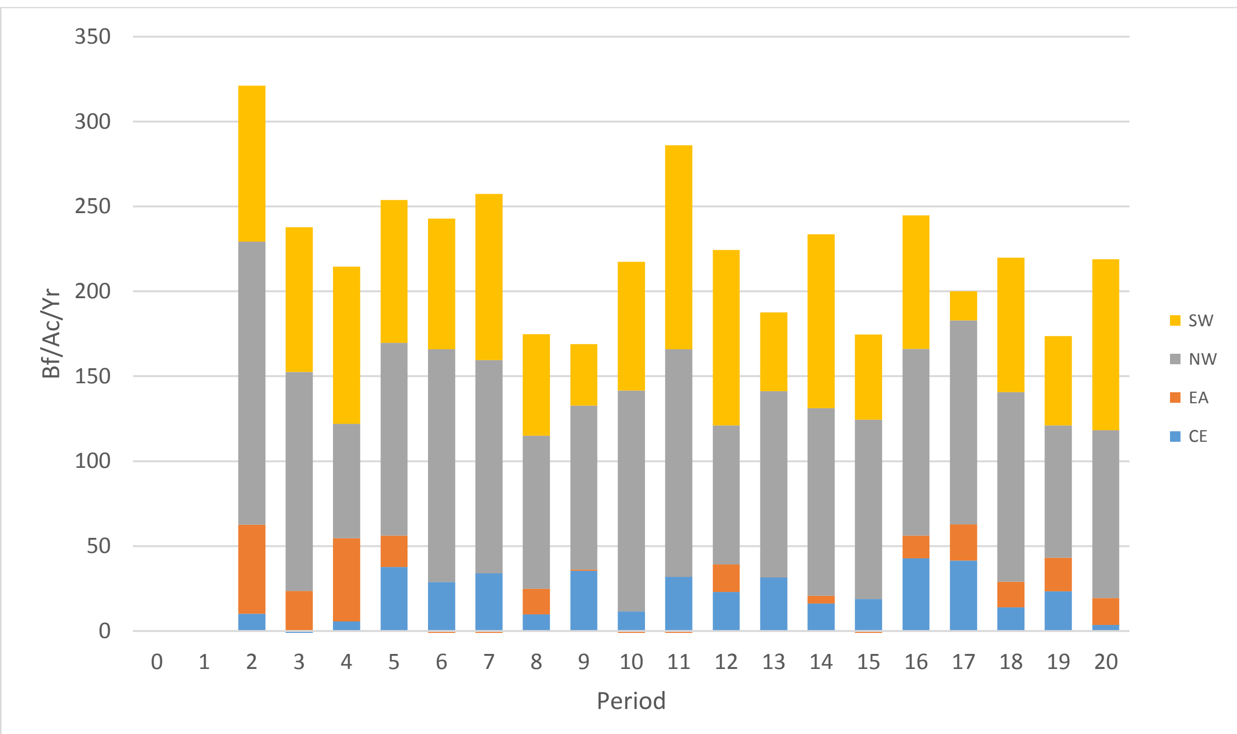


Figure 151: Average Annual Growth Rate – Grizzly Bear Security Zones Constrained

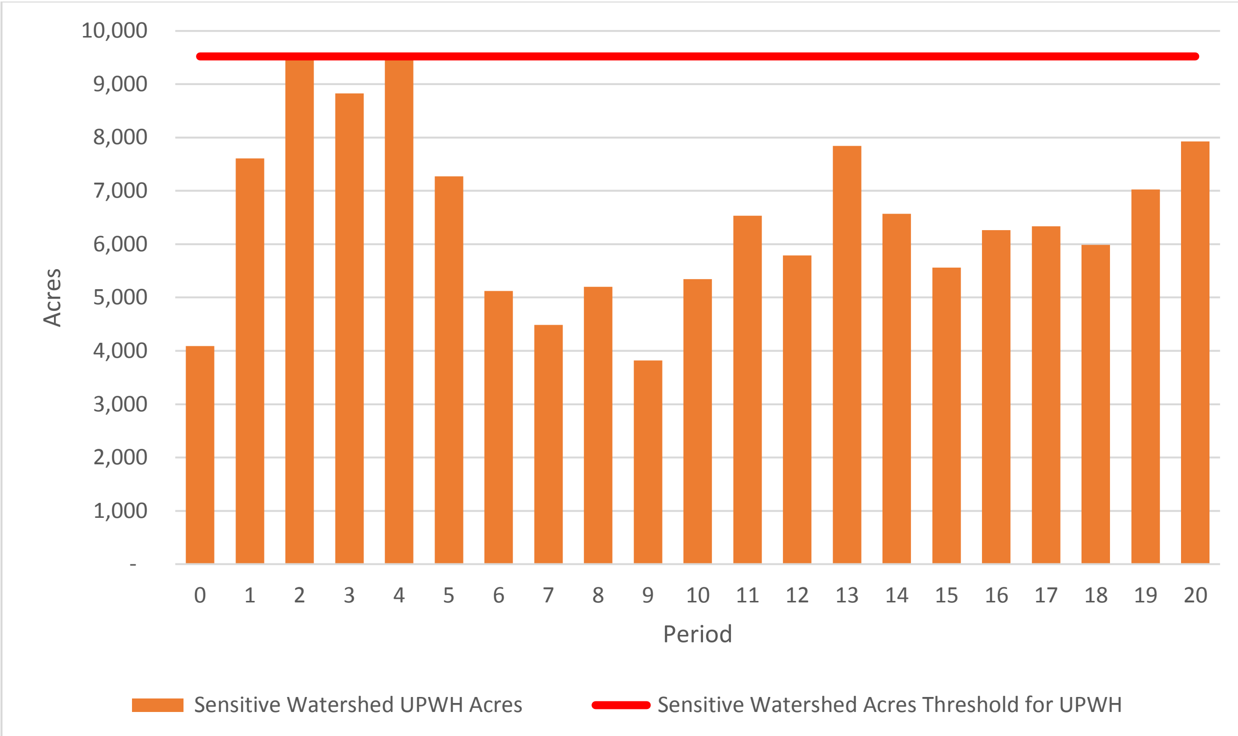


Figure 152: Sensitive Watershed Development (UPWH) – Grizzly Bear Security Zones Constrained

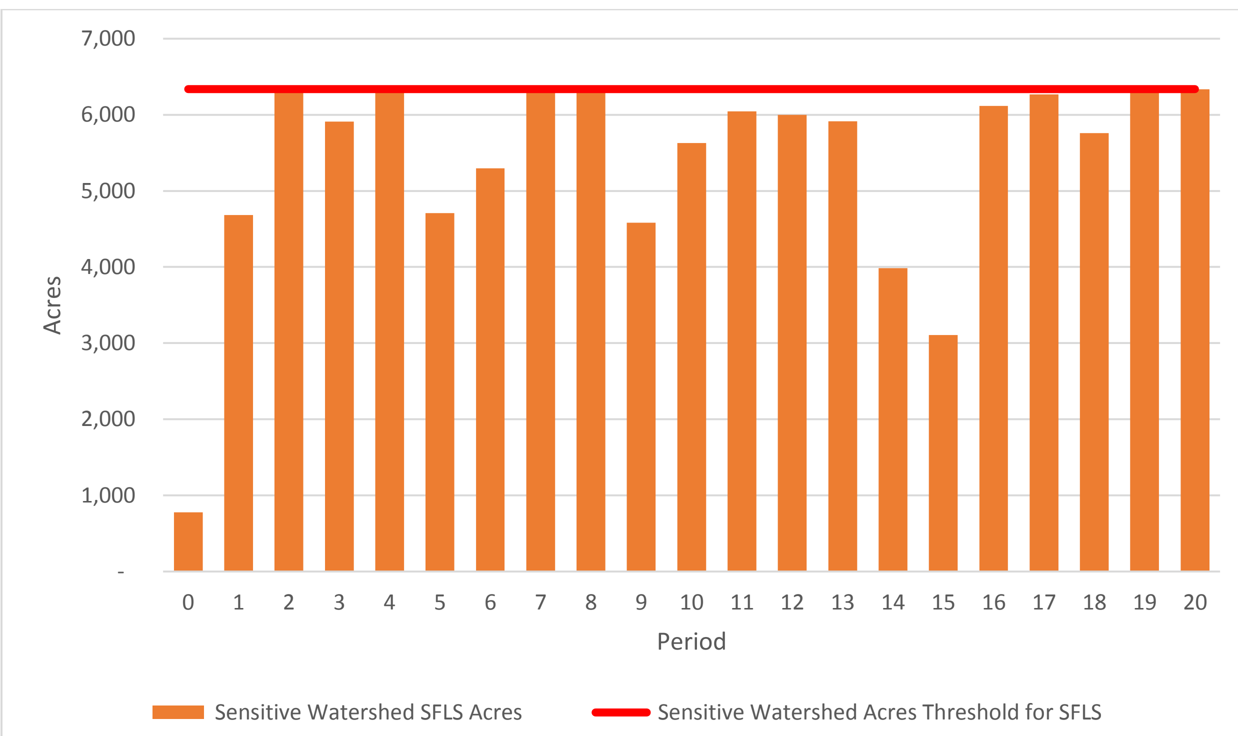


Figure 153: Sensitive Watershed Development (SFLS) – Grizzly Bear Security Zones Constrained

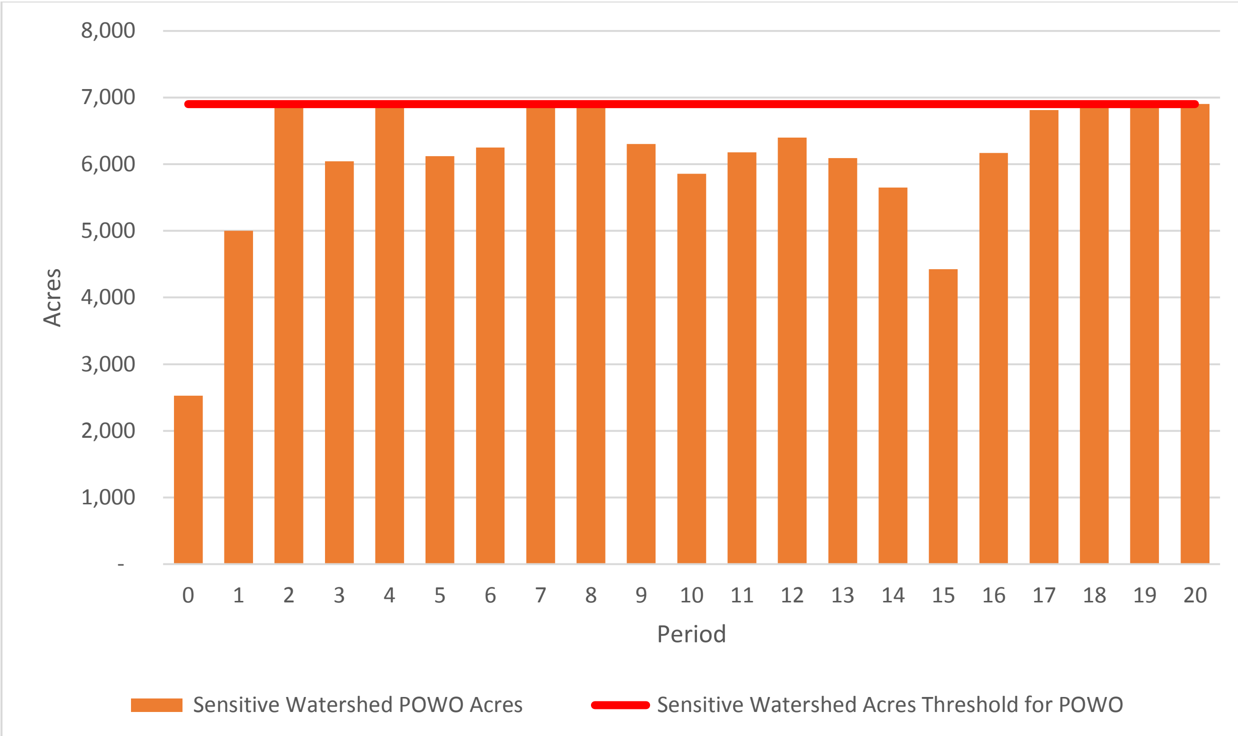


Figure 154: Sensitive Watershed Development (POWO) – Grizzly Bear Security Zones Constrained

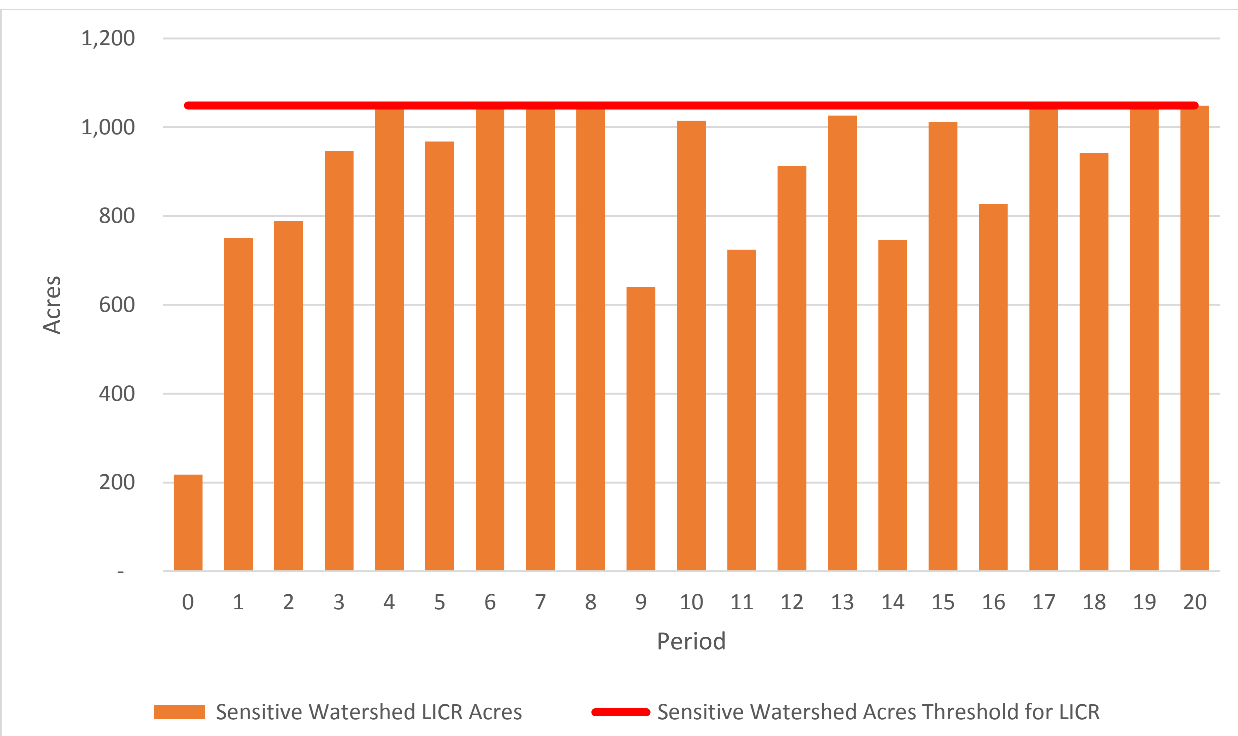


Figure 155: Sensitive Watershed Development (LICR) – Grizzly Bear Security Zones Constrained

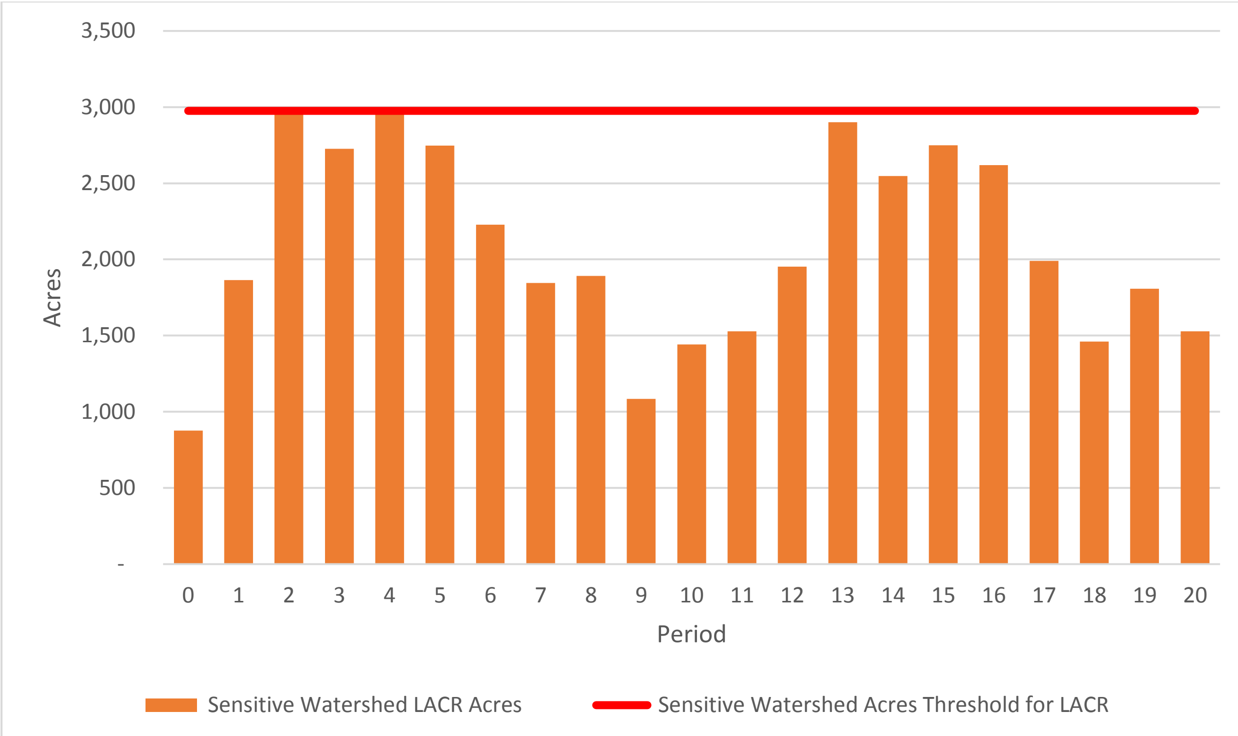


Figure 156: Sensitive Watershed Development (LACR) – Grizzly Bear Security Zones Constrained

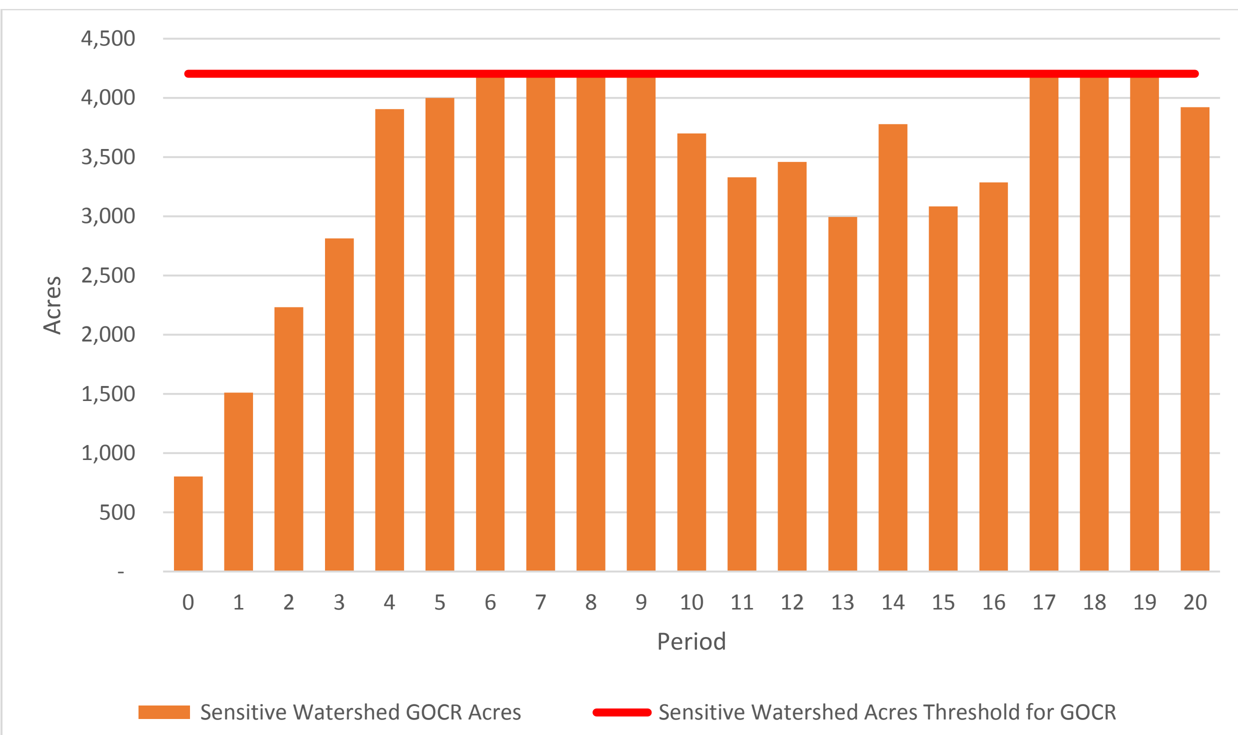


Figure 157: Sensitive Watershed Development (GOCR) – Grizzly Bear Security Zones Constrained

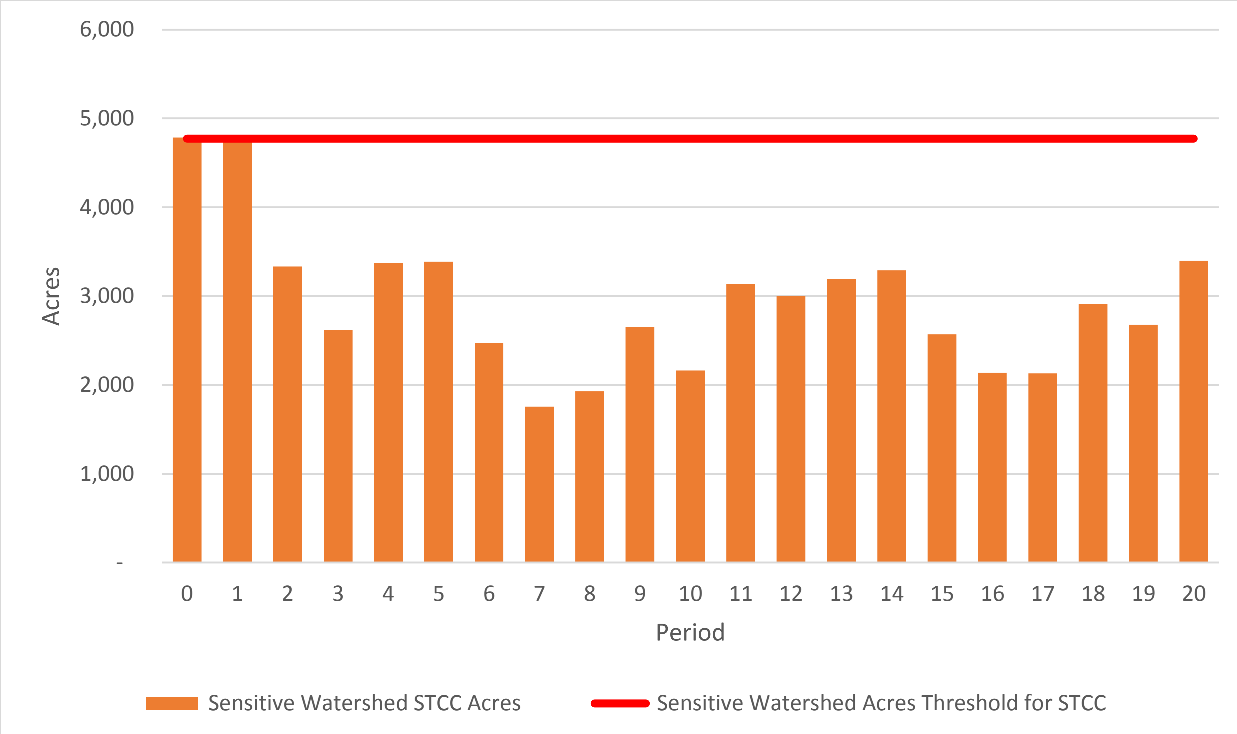


Figure 158: Sensitive Watershed Development (STCC) – Grizzly Bear Security Zones Constrained

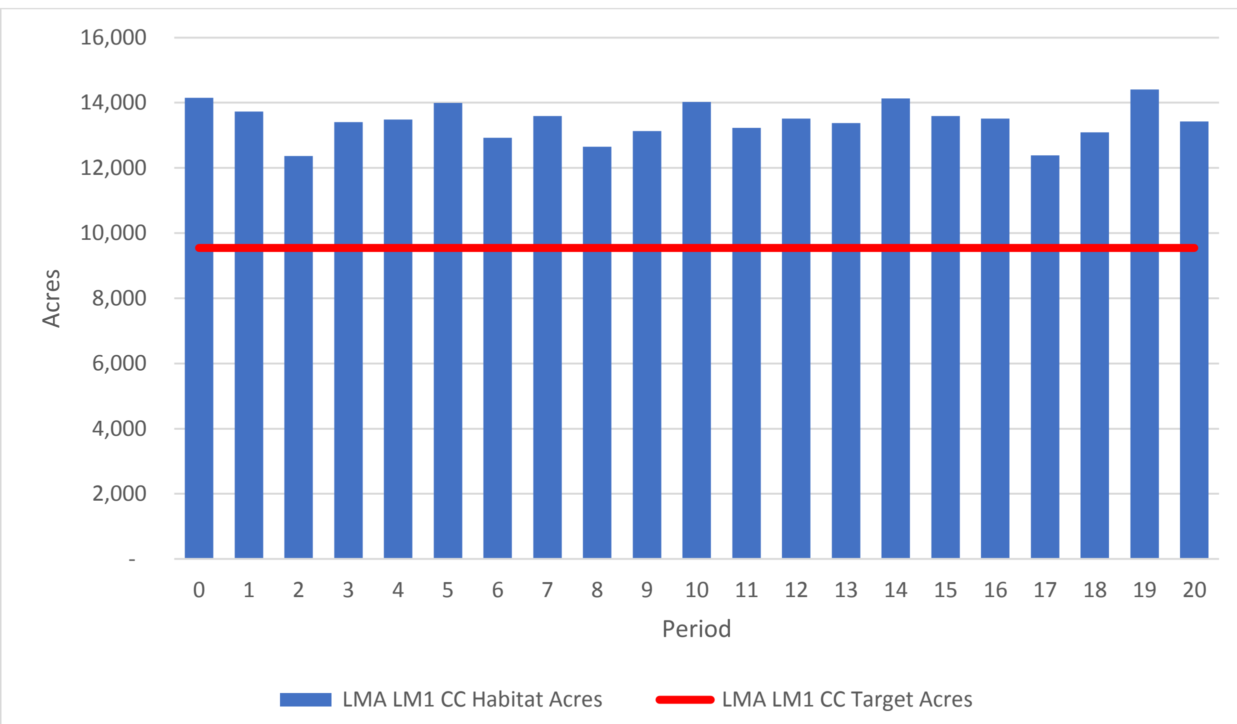


Figure 159: LMA (Coal Creek) Cover Acres – Grizzly Bear Security Zones Constrained

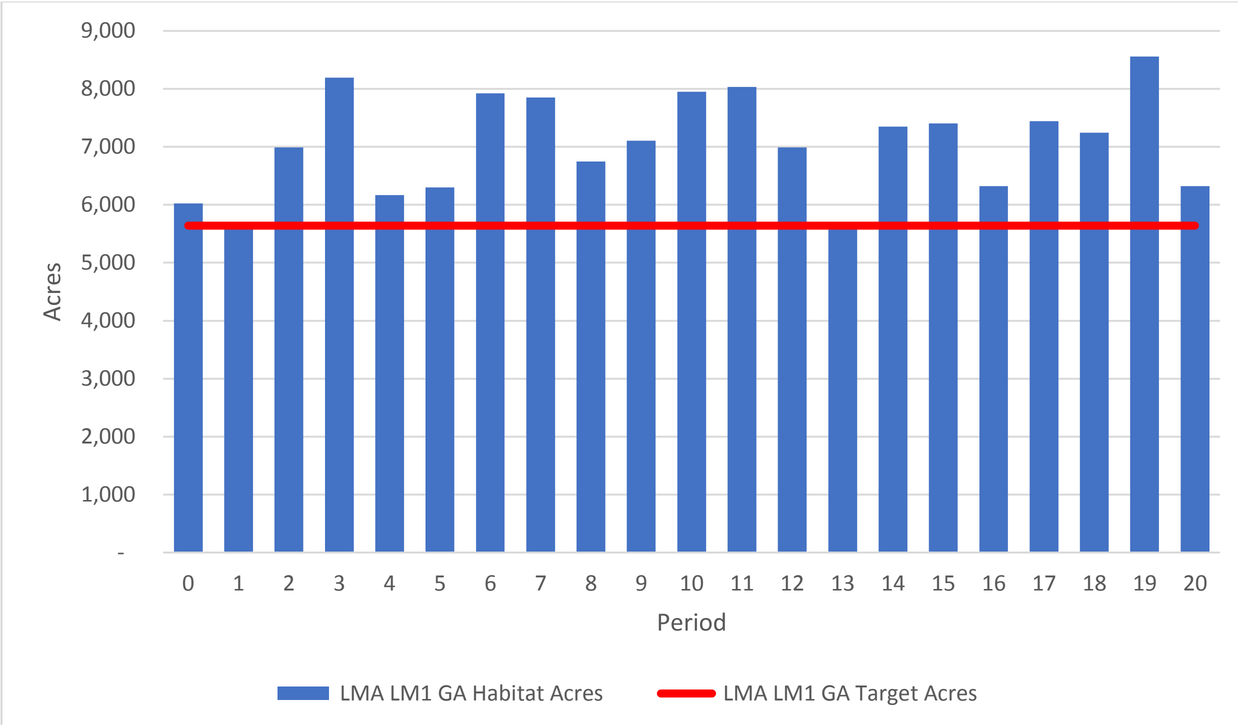


Figure 160: LMA (Garnet) Cover Acres – Grizzly Bear Security Zones Constrained

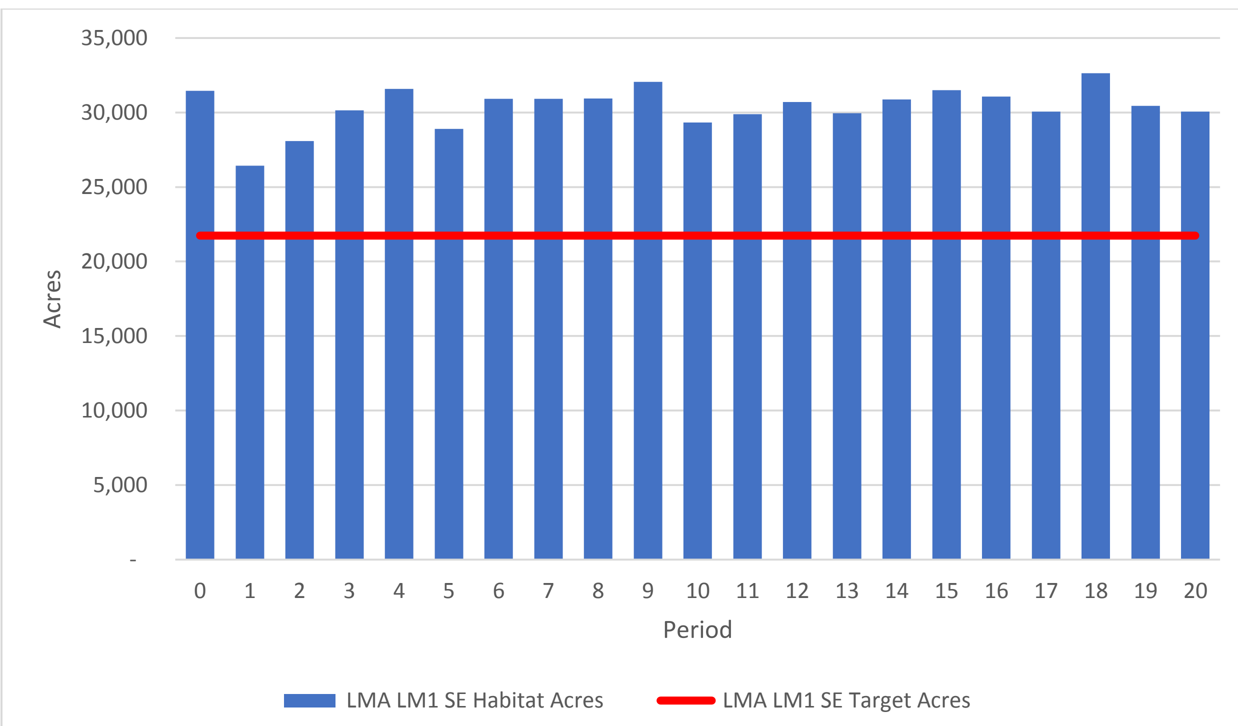


Figure 161: LMA (Stillwater East) Cover Acres – Grizzly Bear Security Zones Constrained

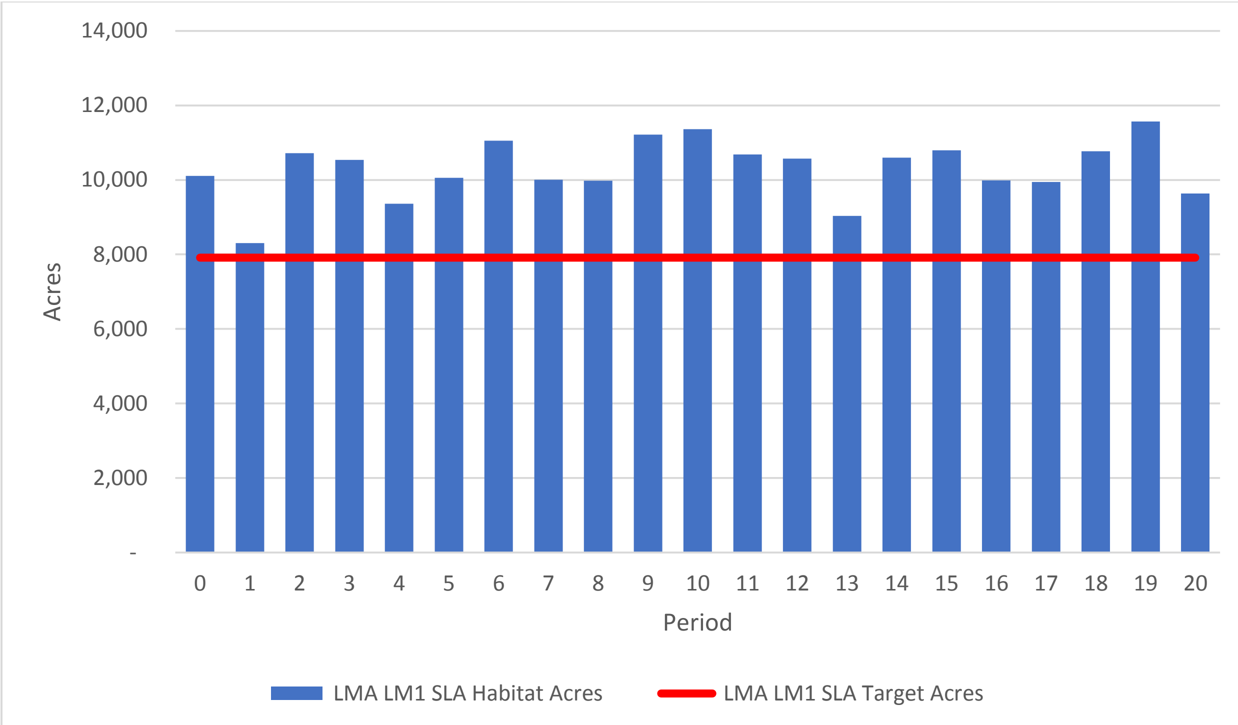


Figure 162: LMA (Seeley Lake) Cover Acres – Grizzly Bear Security Zones Constrained

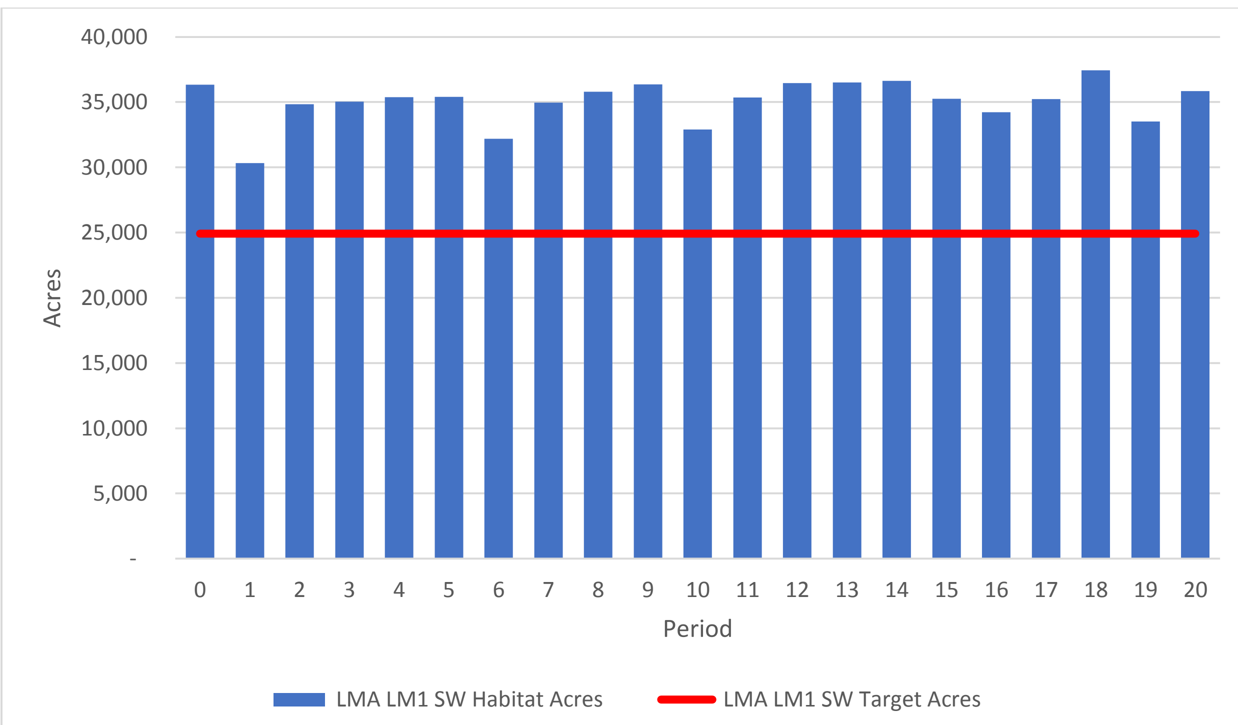


Figure 163: LMA (Stillwater West) Cover Acres – Grizzly Bear Security Zones Constrained

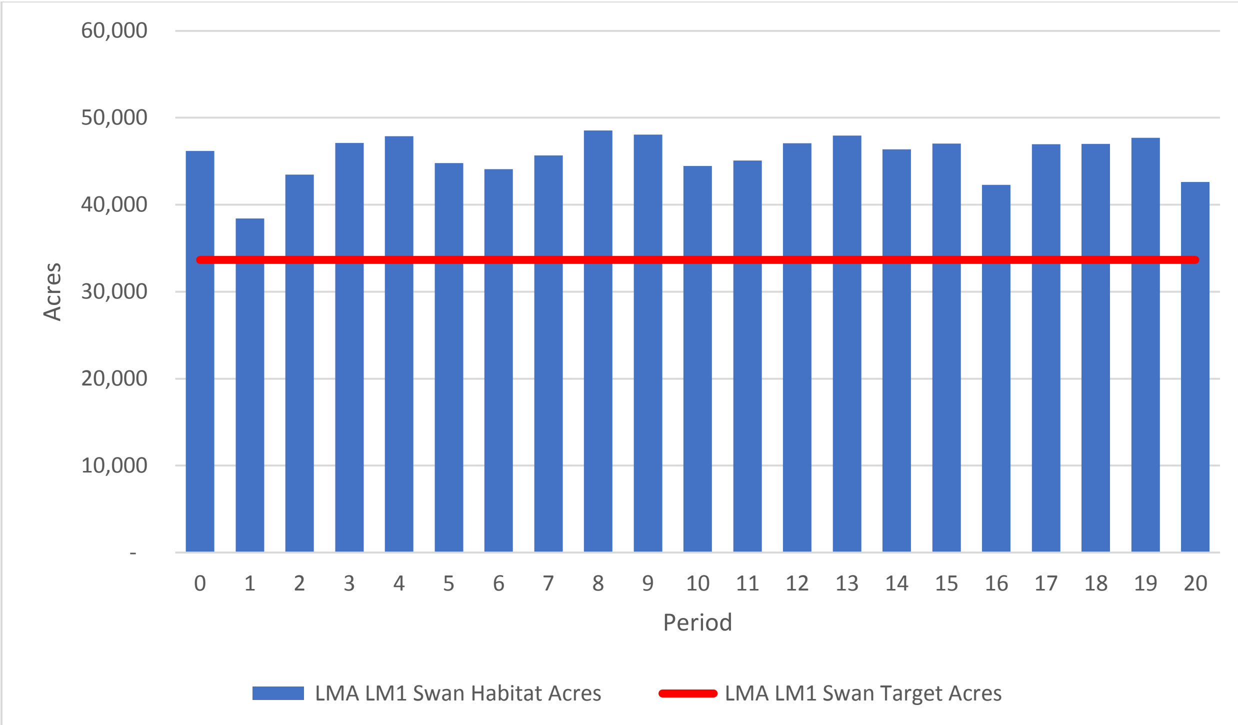


Figure 164: LMA (Swan) Cover Acres – Grizzly Bear Security Zones Constrained

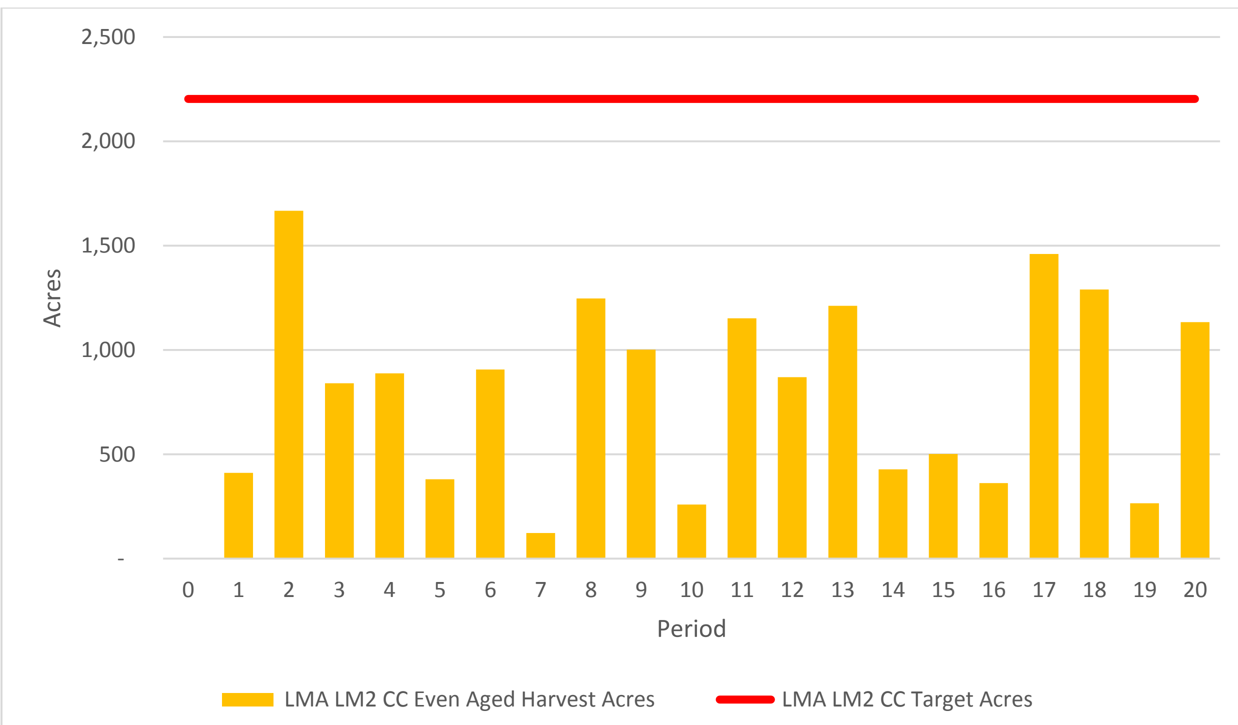


Figure 165: LMA (Coal Creek) EA Harvest Acres – Grizzly Bear Security Zones Constrained

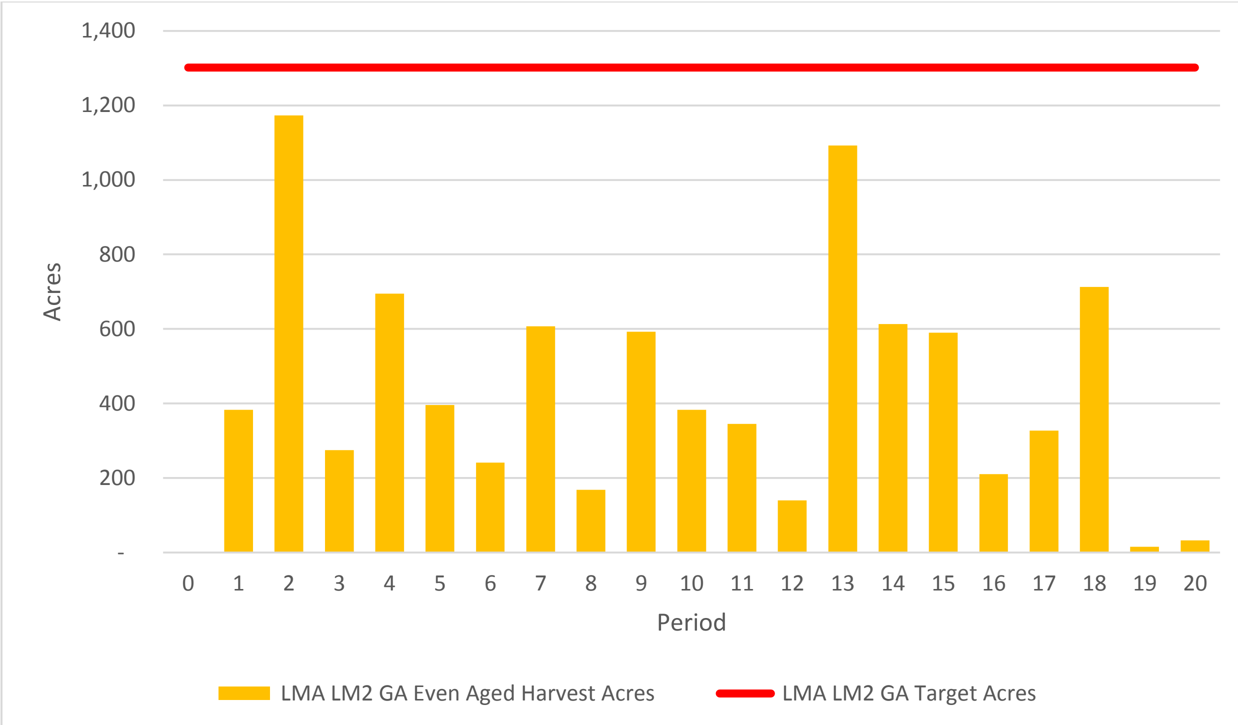


Figure 166: LMA (Garnet) EA Harvest Acres – Grizzly Bear Security Zones Constrained

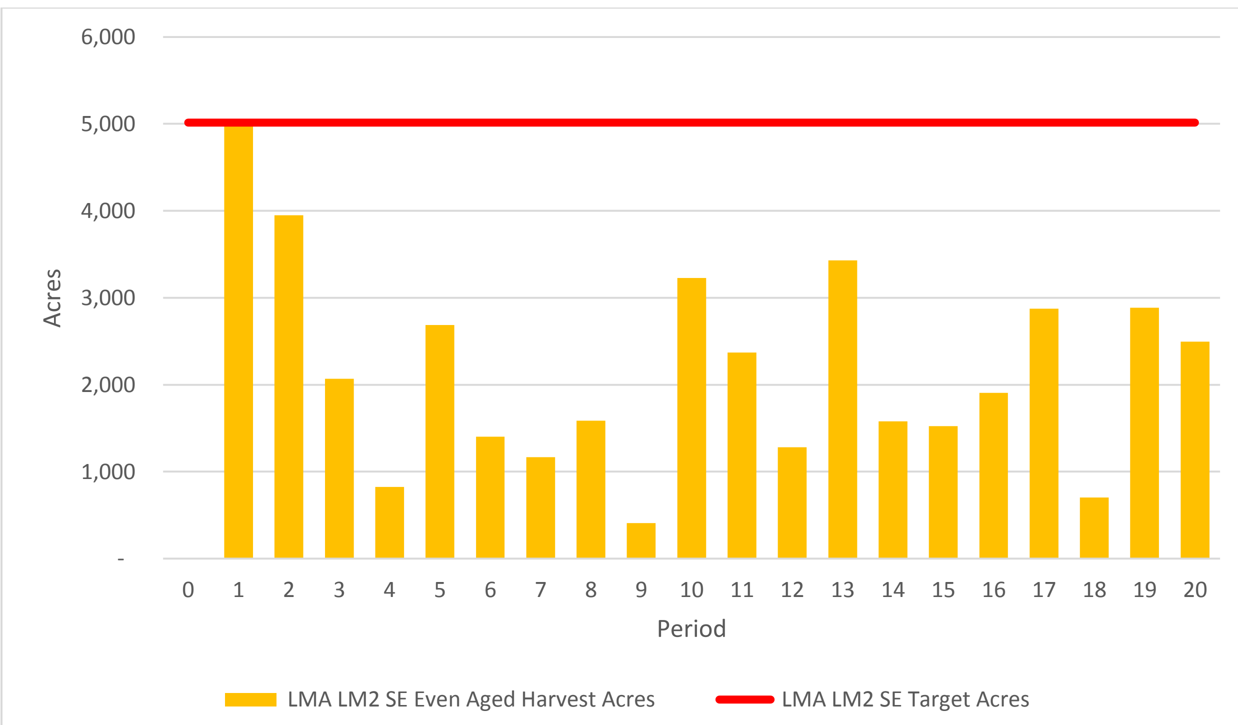


Figure 167: LMA (Stillwater East) EA Harvest Acres – Grizzly Bear Security Zones Constrained

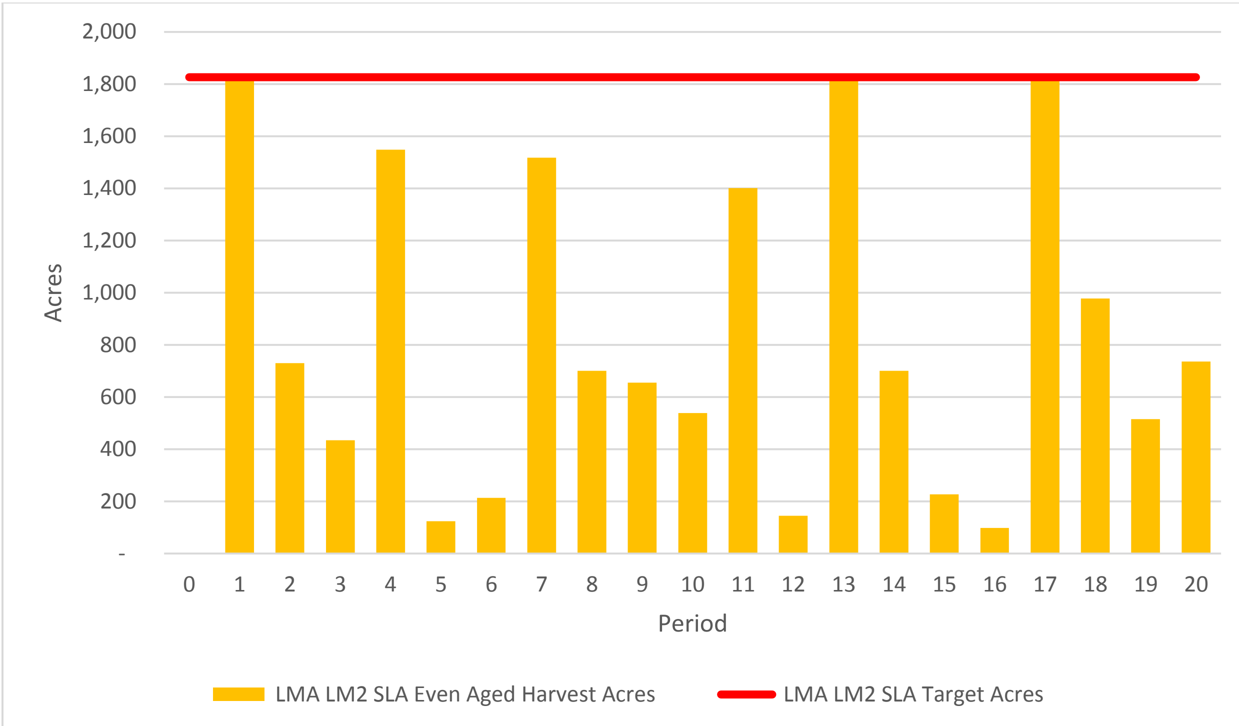


Figure 168: LMA (Seeley Lake) EA Harvest Acres – Grizzly Bear Security Zones Constrained

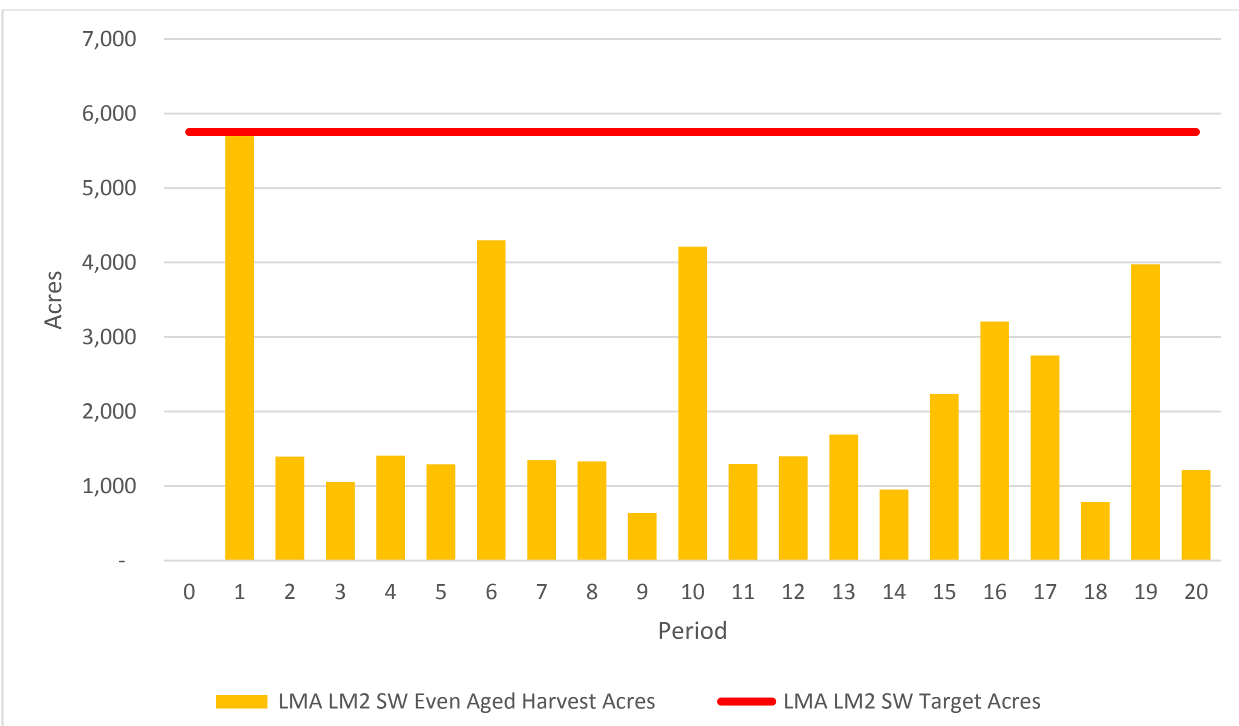


Figure 169: LMA (Stillwater West) EA Harvest Acres – Grizzly Bear Security Zones Constrained

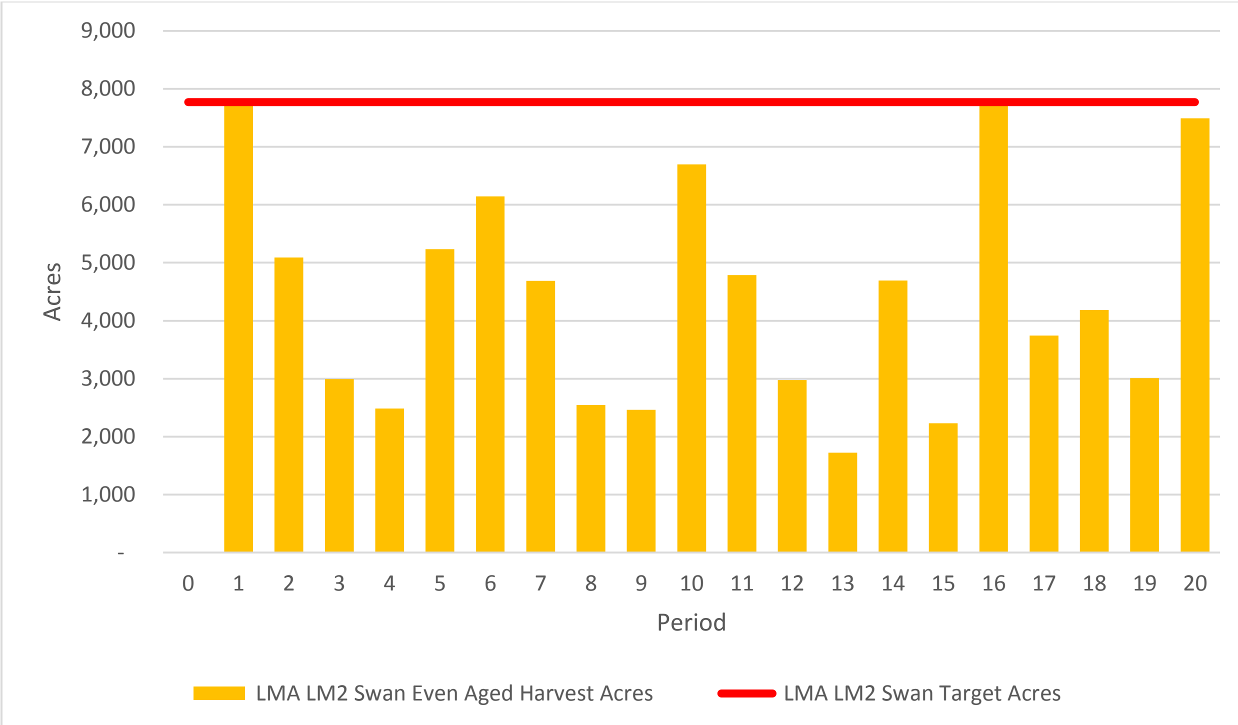


Figure 170: LMA (Swan) EA Harvest Acres – Grizzly Bear Security Zones Constrained

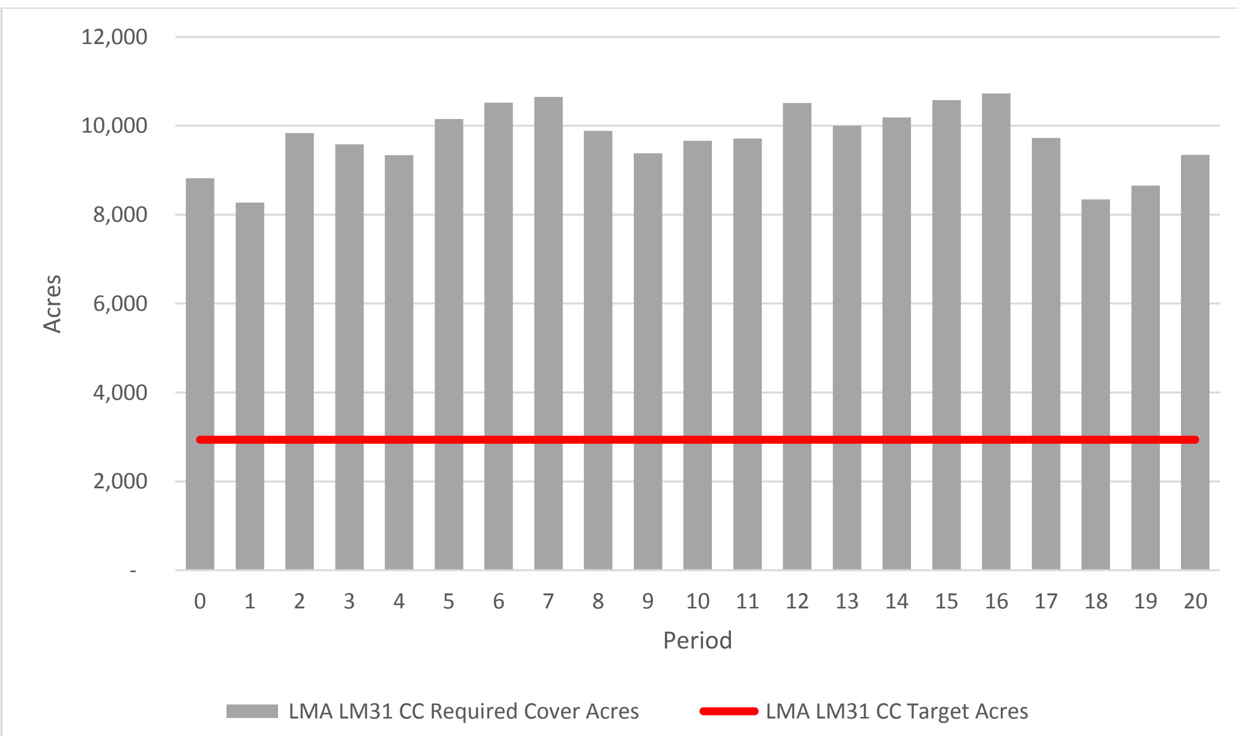


Figure 171: LMA (Coal Creek) Saw-Timber Acres – Grizzly Bear Security Zones Constrained

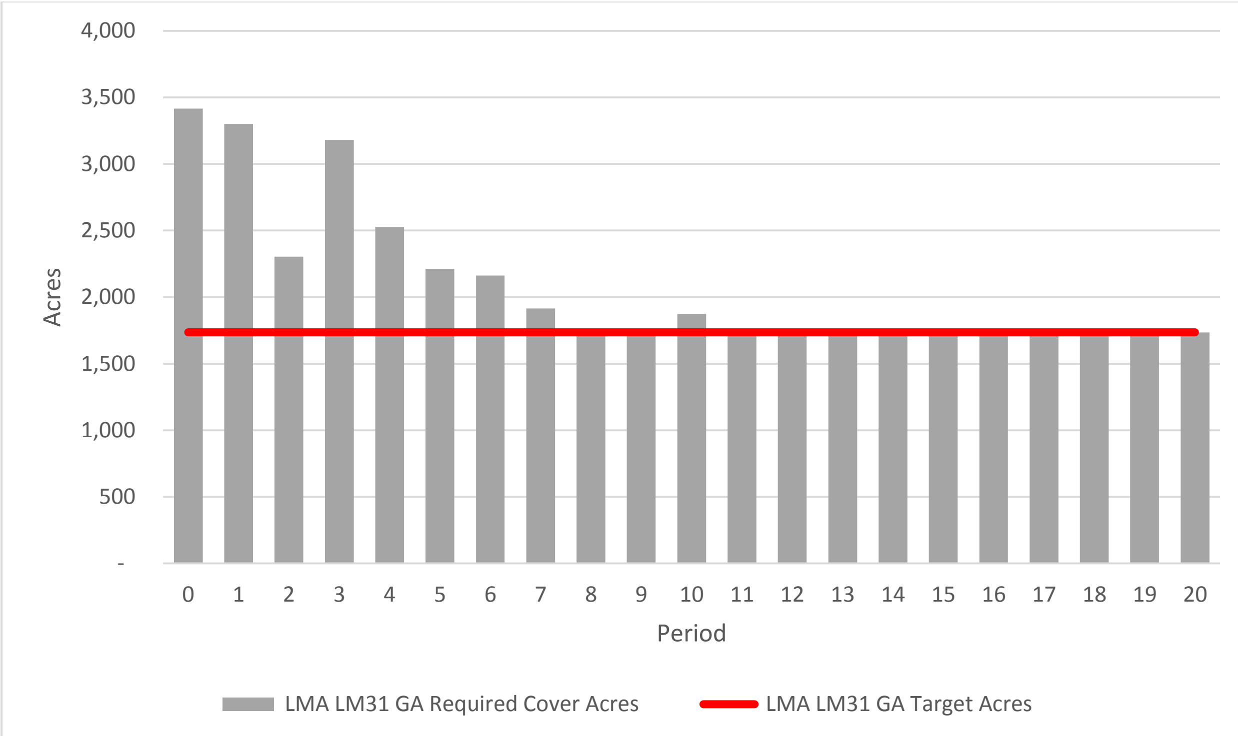


Figure 172: LMA (Garnet) Saw-Timber Acres – Grizzly Bear Security Zones Constrained

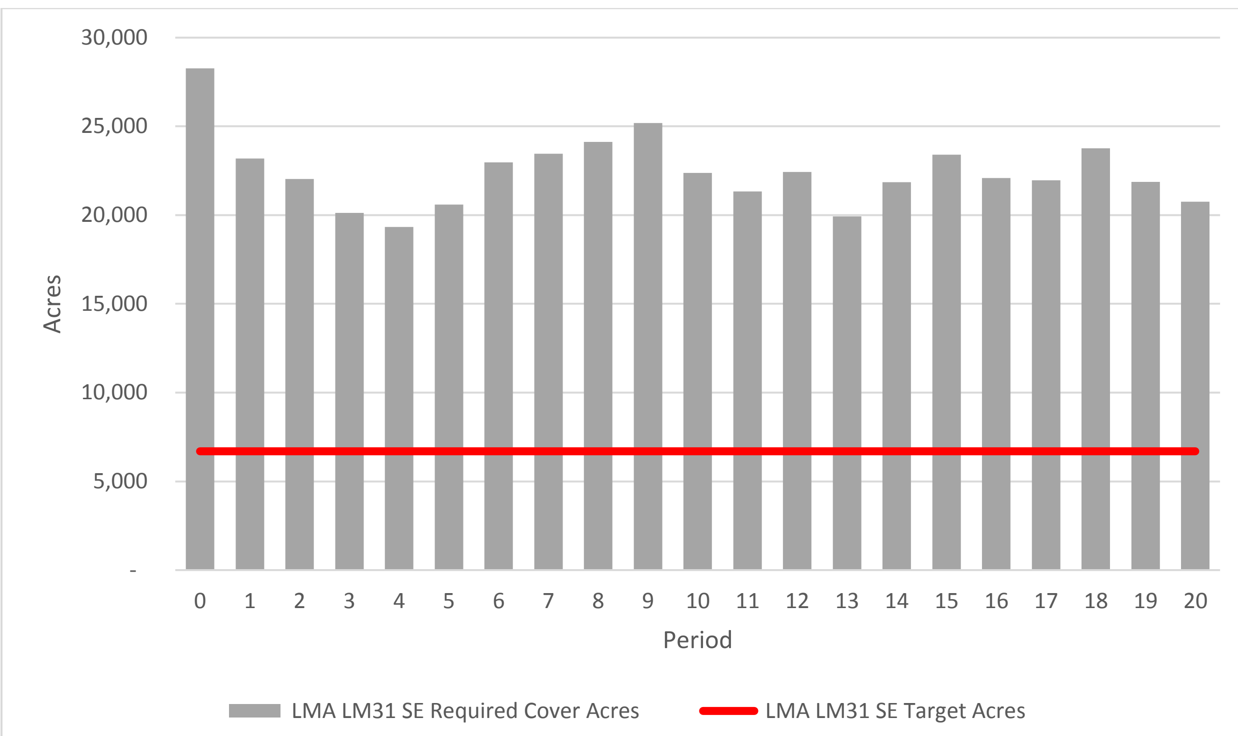


Figure 173: LMA (Stillwater East) Saw-Timber Acres – Grizzly Bear Security Zones Constrained

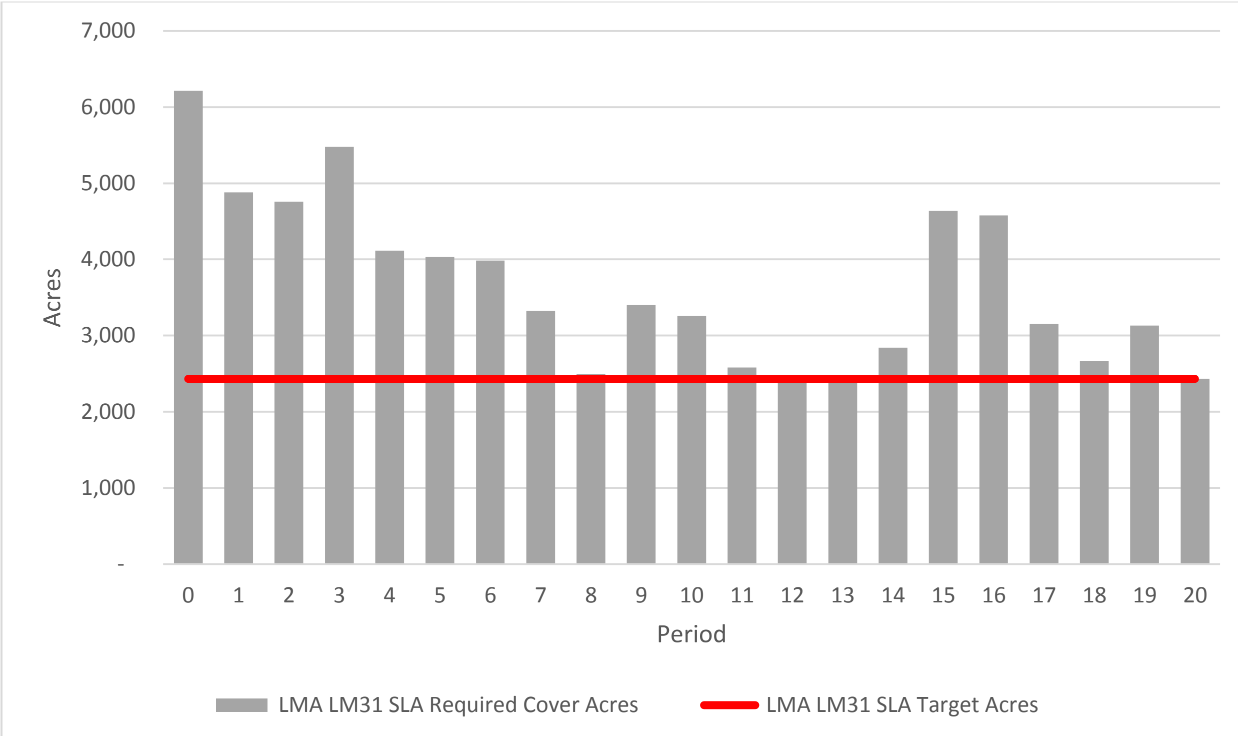


Figure 174: LMA (Seeley Lake) Saw-Timber Acres – Grizzly Bear Security Zones Constrained

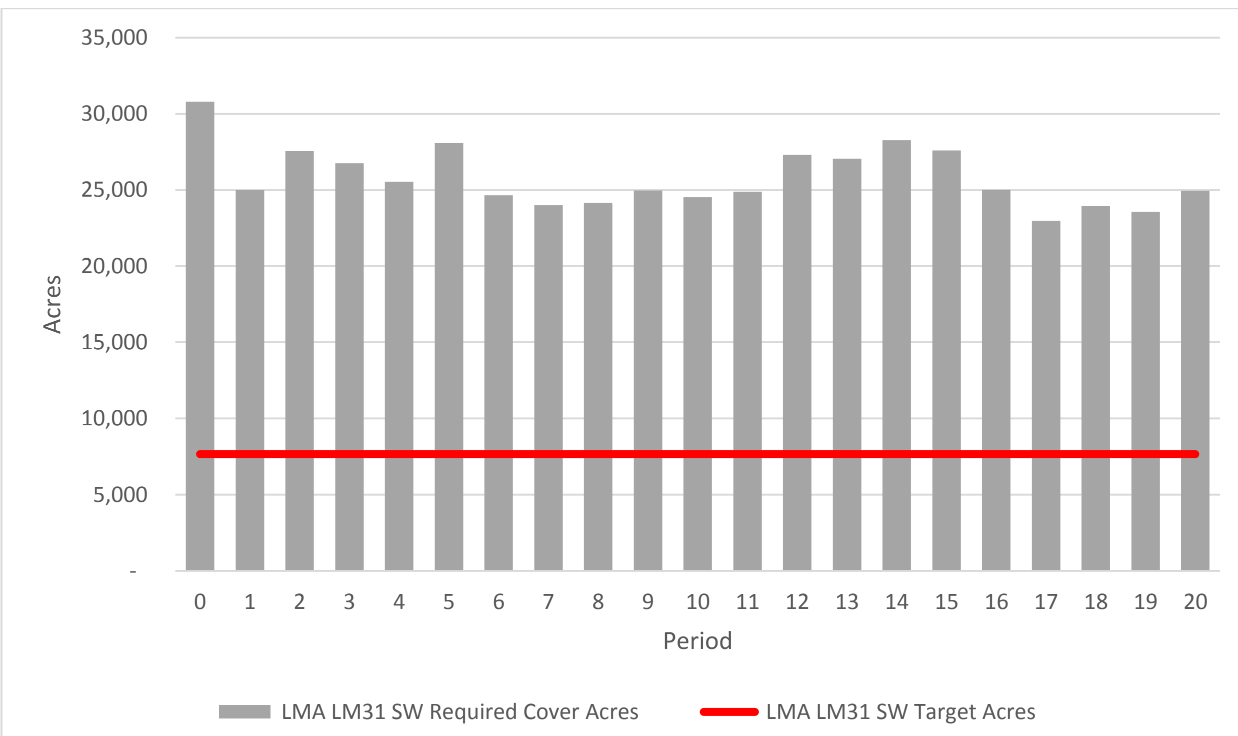


Figure 175: LMA (Stillwater West) Saw-Timber Acres – Grizzly Bear Security Zones Constrained

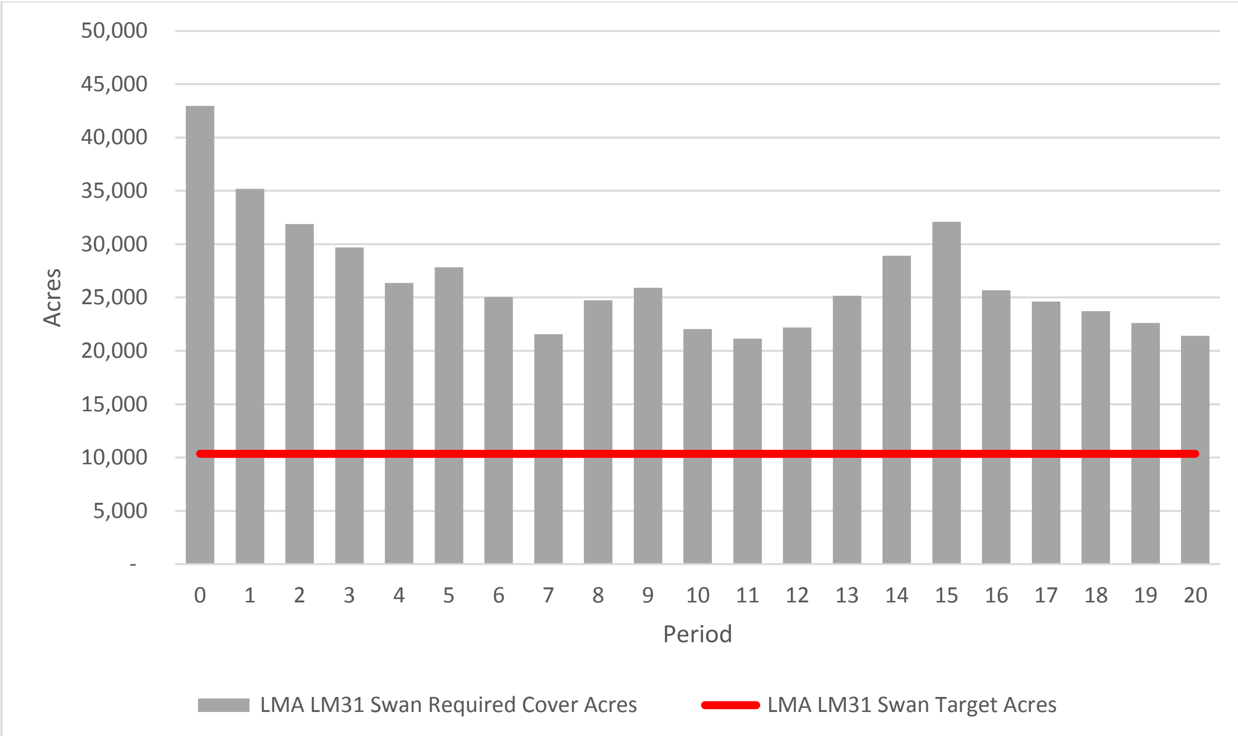


Figure 176: LMA (Swan) Saw-Timber Acres – Grizzly Bear Security Zones Constrained

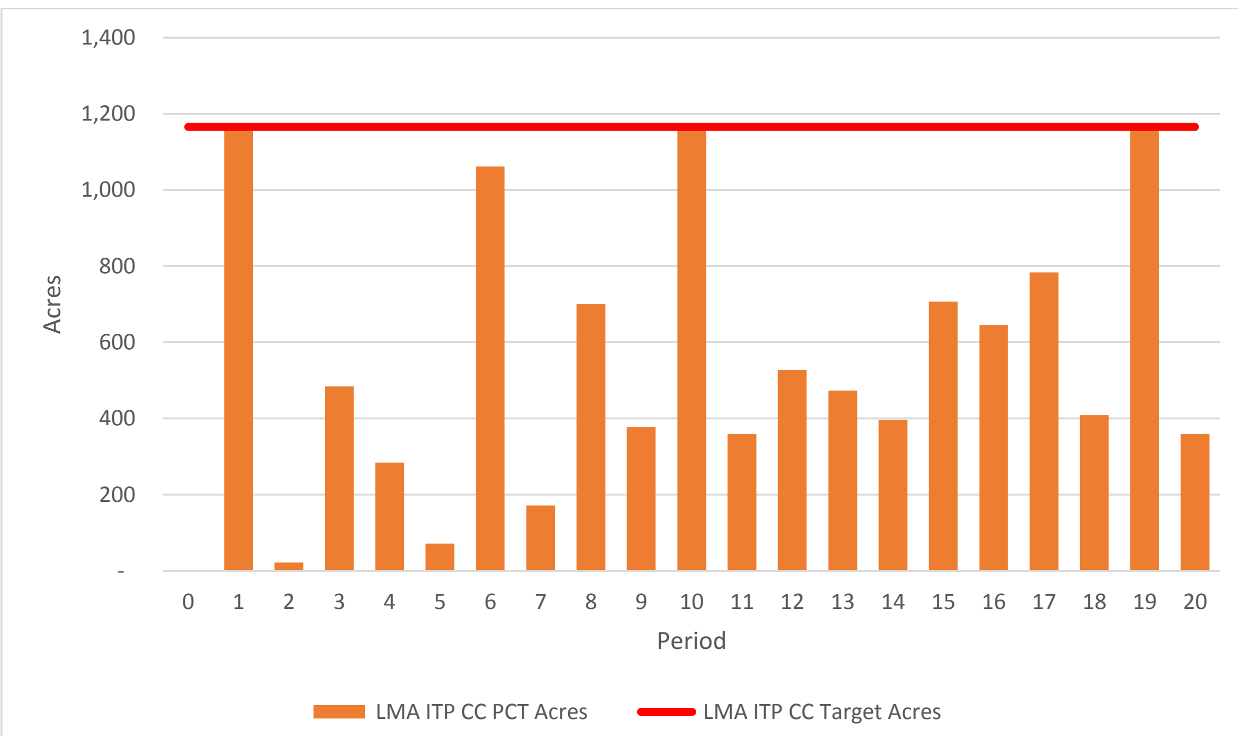


Figure 177: LMA (Coal Creek) PCT Acres – Grizzly Bear Security Zones Constrained

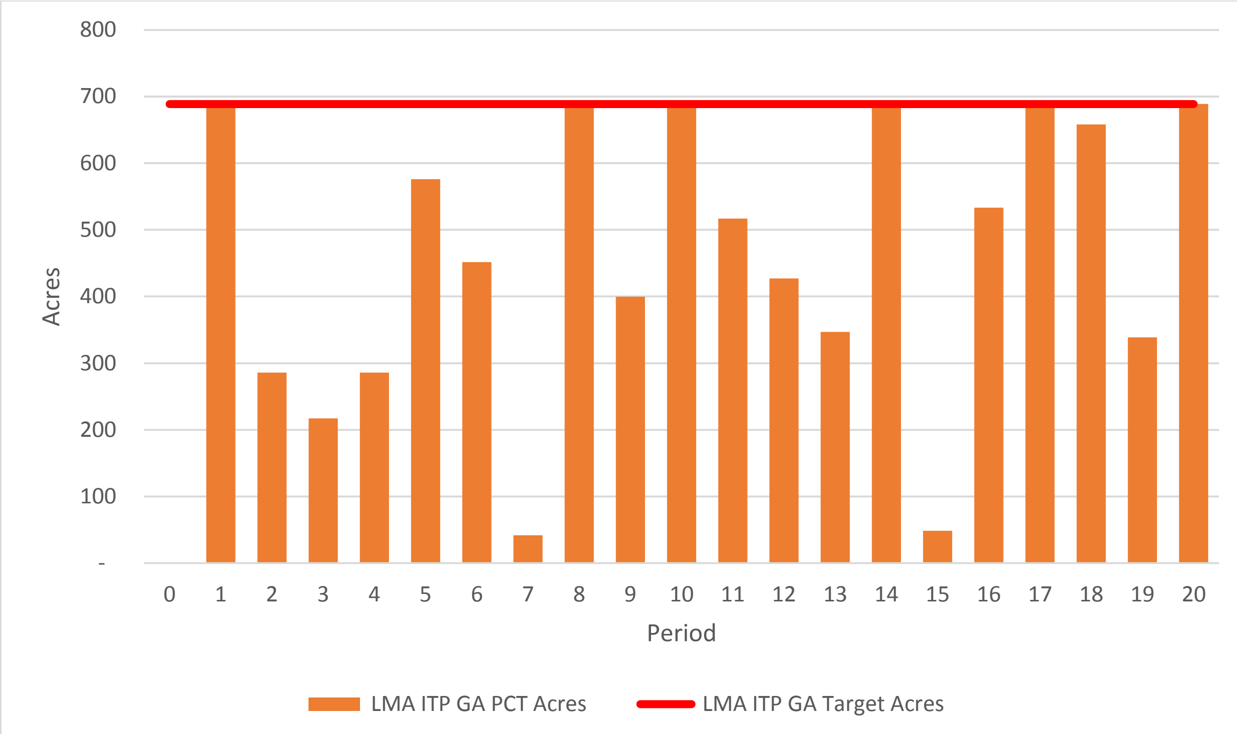


Figure 178: LMA (Garnet) PCT Acres – Grizzly Bear Security Zones Constrained

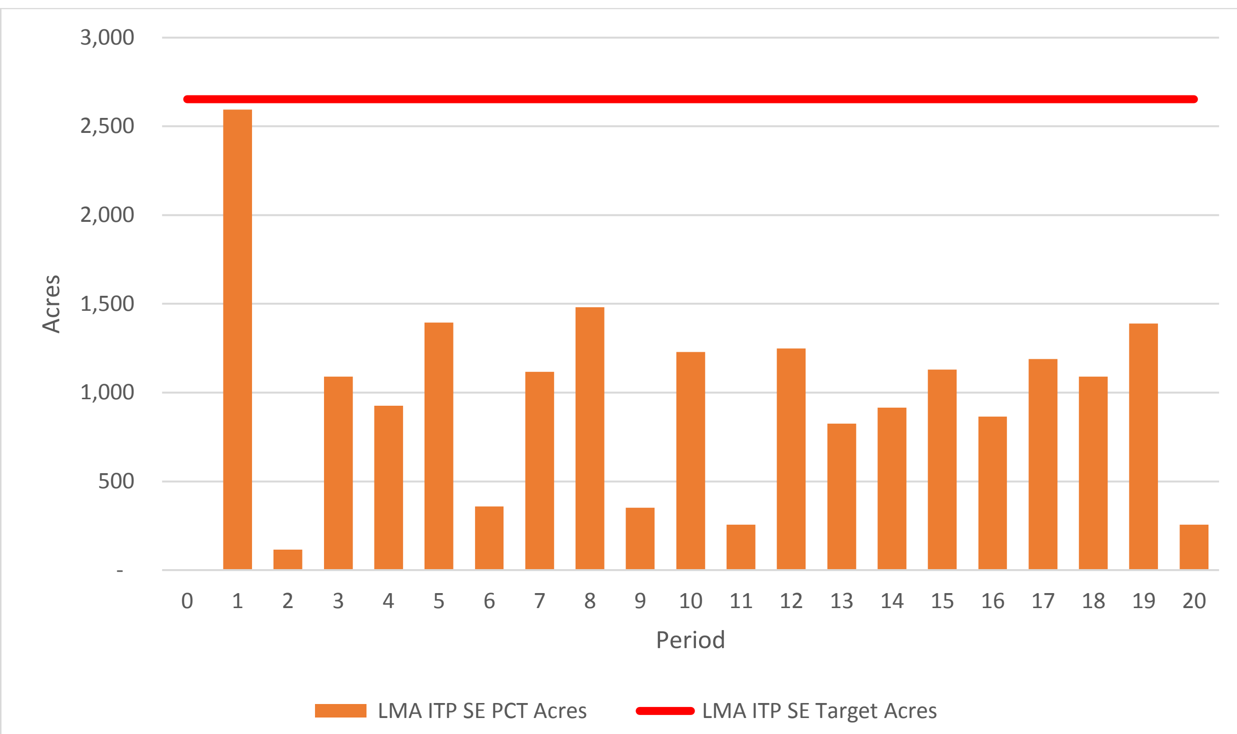


Figure 179: LMA (Stillwater East) PCT Acres – Grizzly Bear Security Zones Constrained

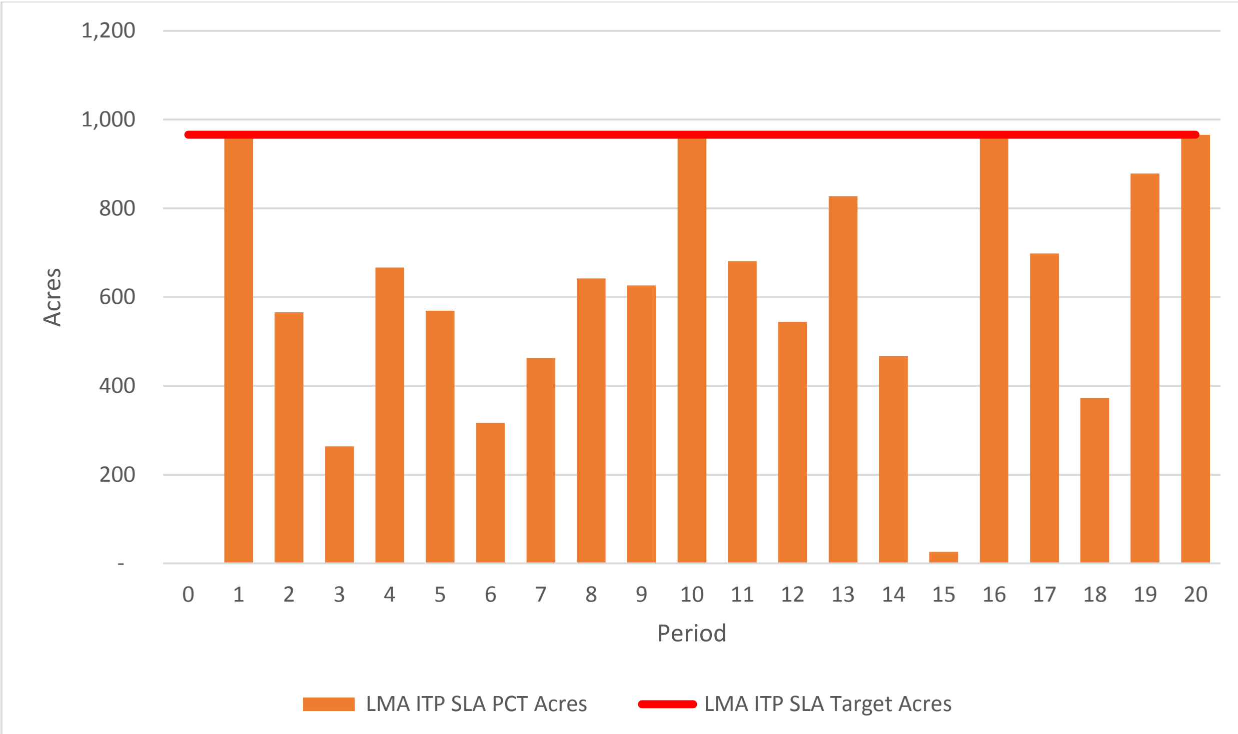


Figure 180: LMA (Seeley Lake) PCT Acres – Grizzly Bear Security Zones Constrained

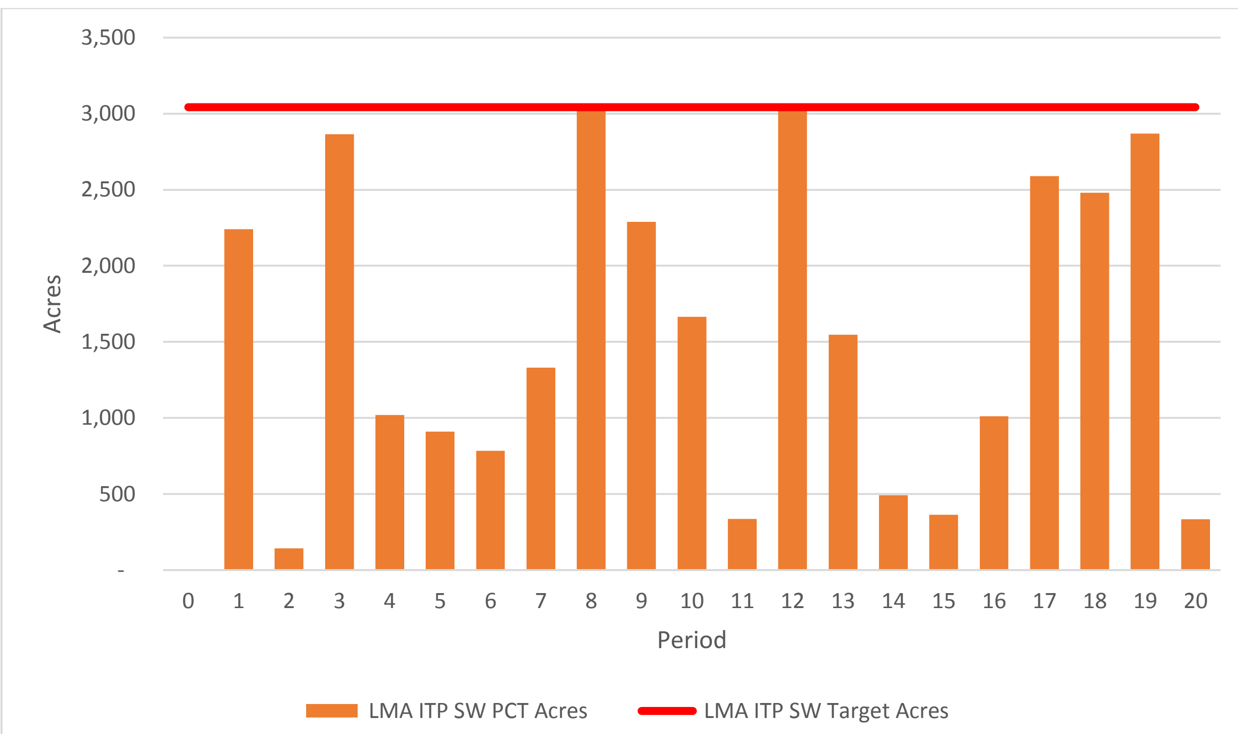


Figure 181: LMA (Stillwater West) PCT Acres – Grizzly Bear Security Zones Constrained

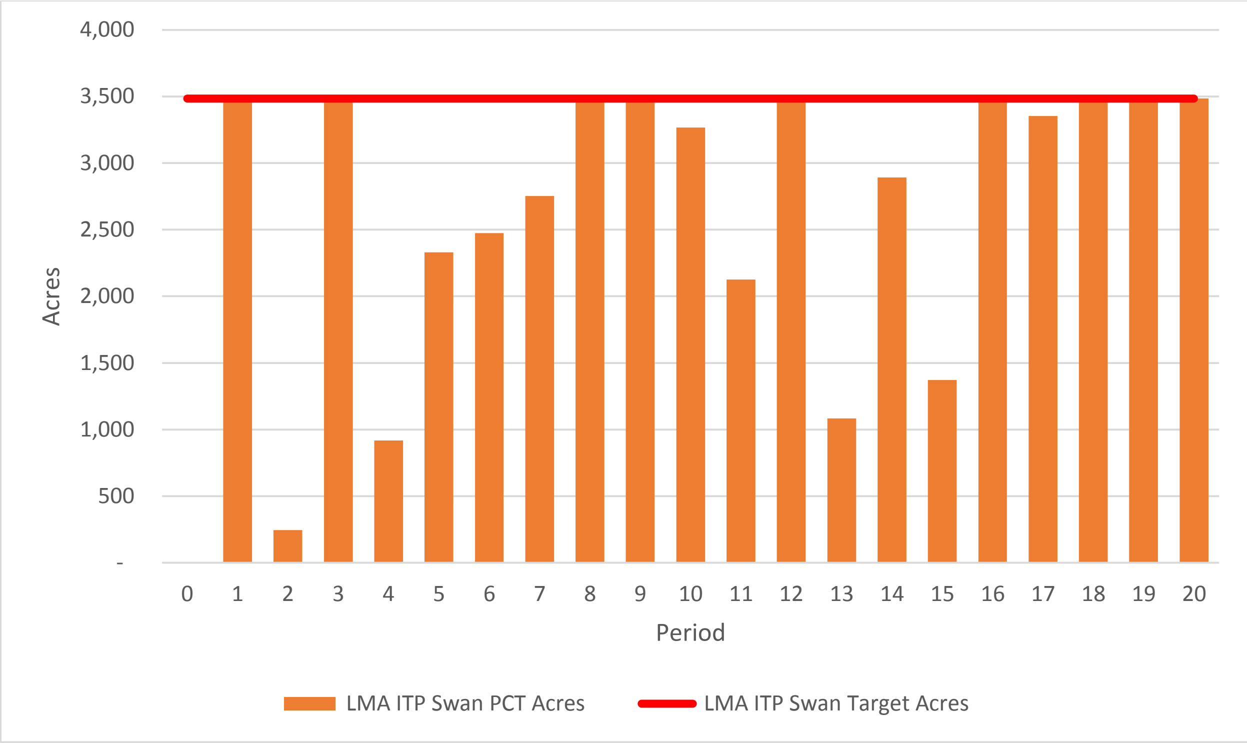


Figure 182: LMA (Swan) PCT Acres – Grizzly Bear Security Zones Constrained

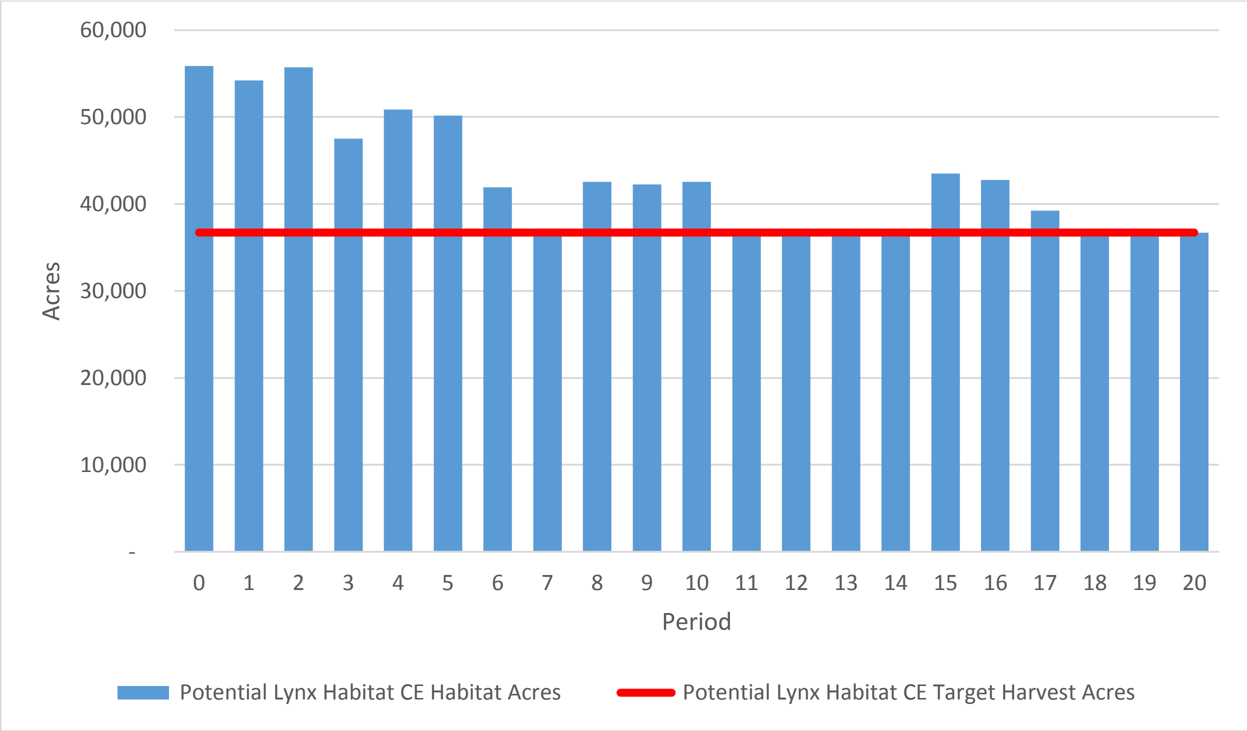


Figure 183: Potential Lynx Habitat Development (CE) – Grizzly Bear Security Zones Constrained

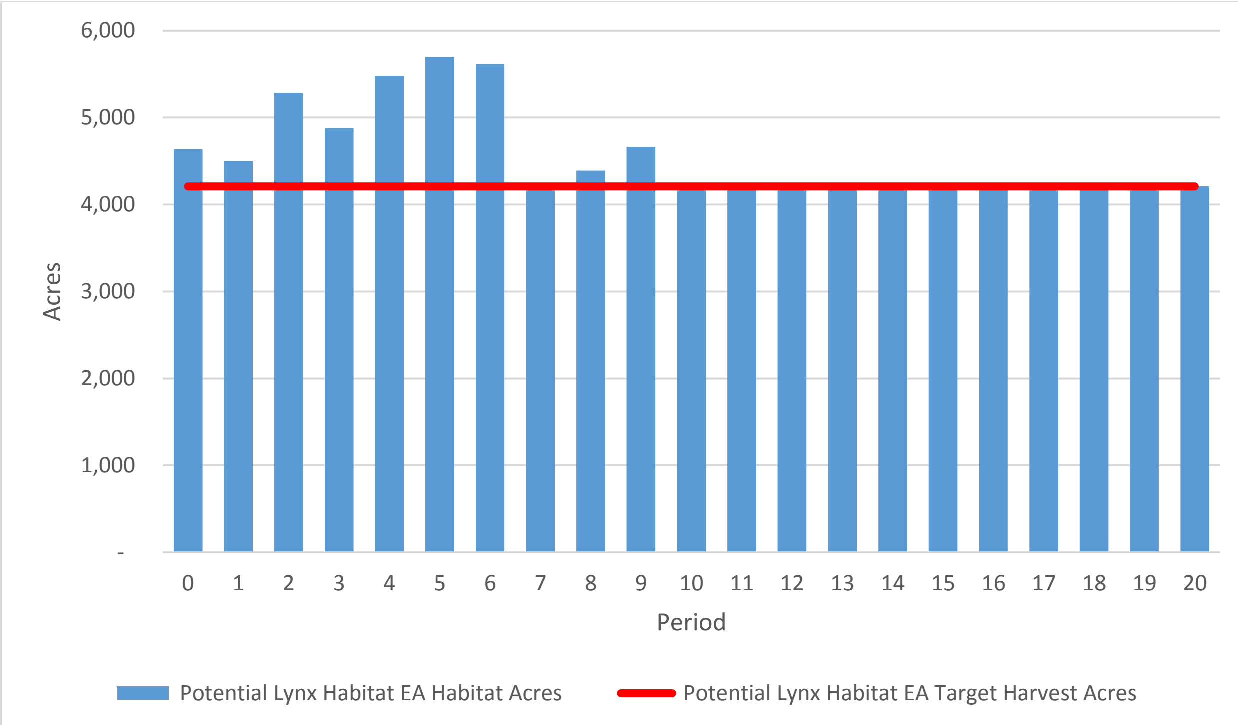


Figure 184: Potential Lynx Habitat Development (EA) – Grizzly Bear Security Zones Constrained

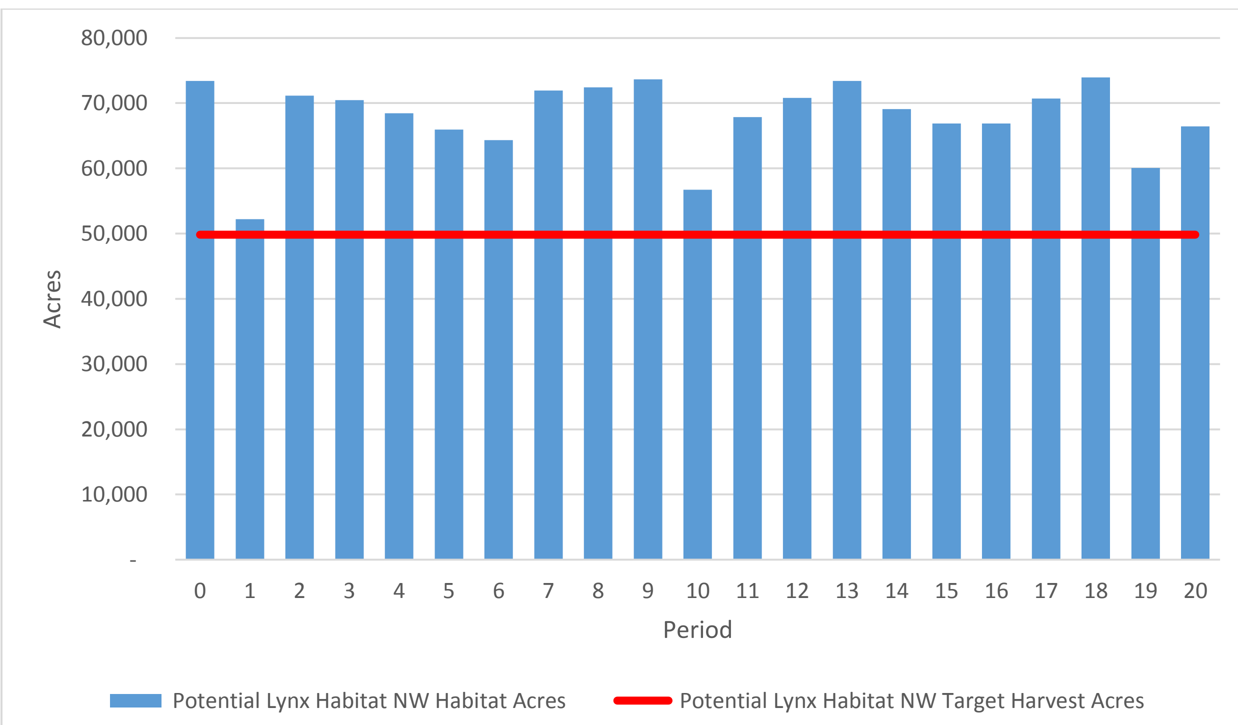


Figure 185: Potential Lynx Habitat Development (NW) – Grizzly Bear Security Zones Constrained

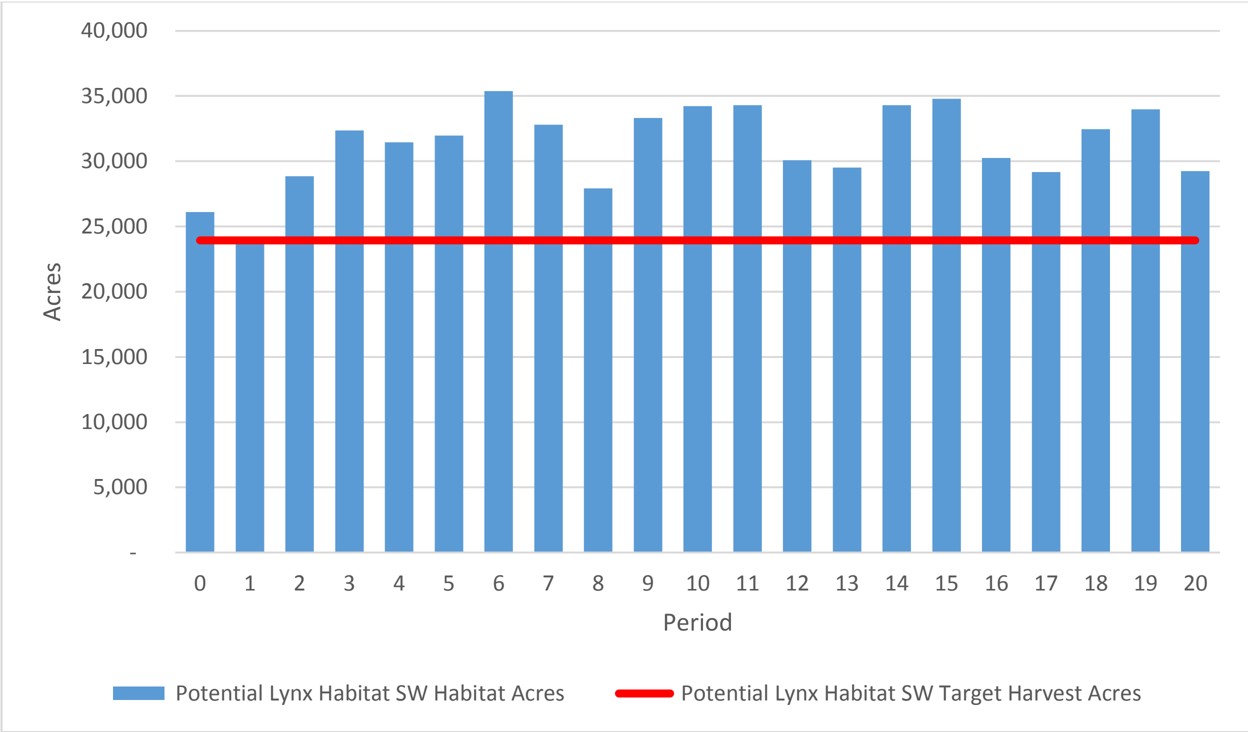


Figure 186: Potential Lynx Habitat Development (SW) – Grizzly Bear Security Zones Constrained

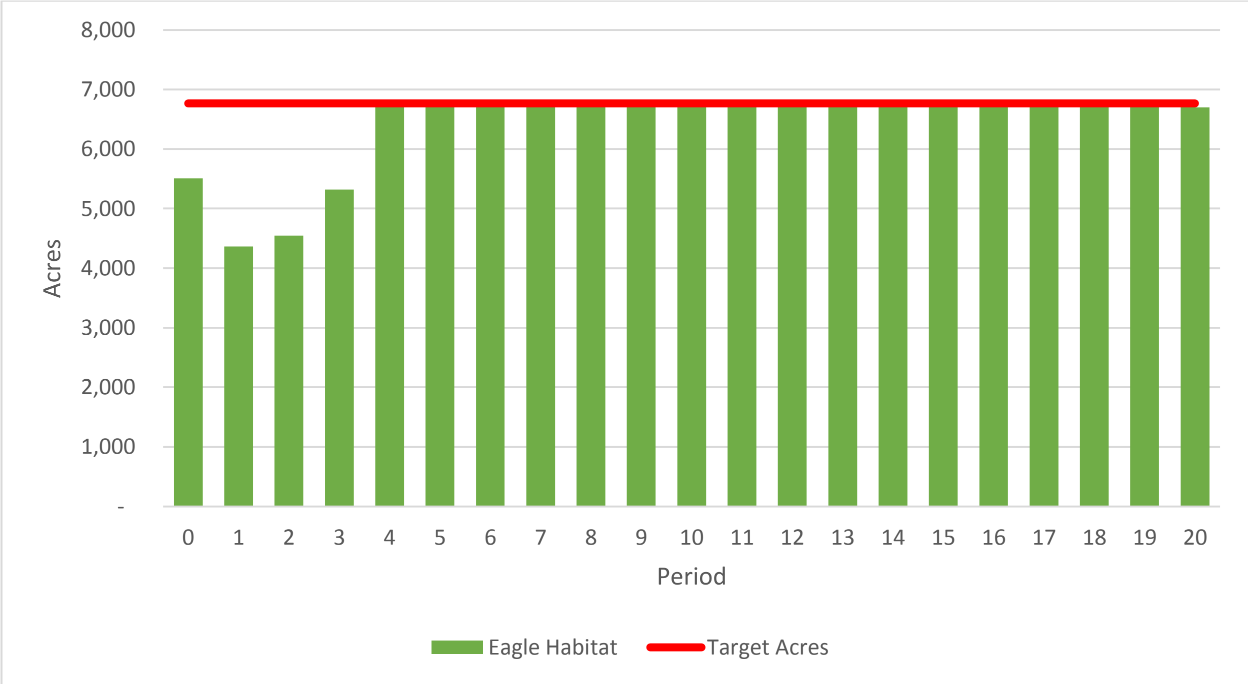


Figure 187: Bald Eagle Habitat Acres – Grizzly Bear Security Zones Constrained

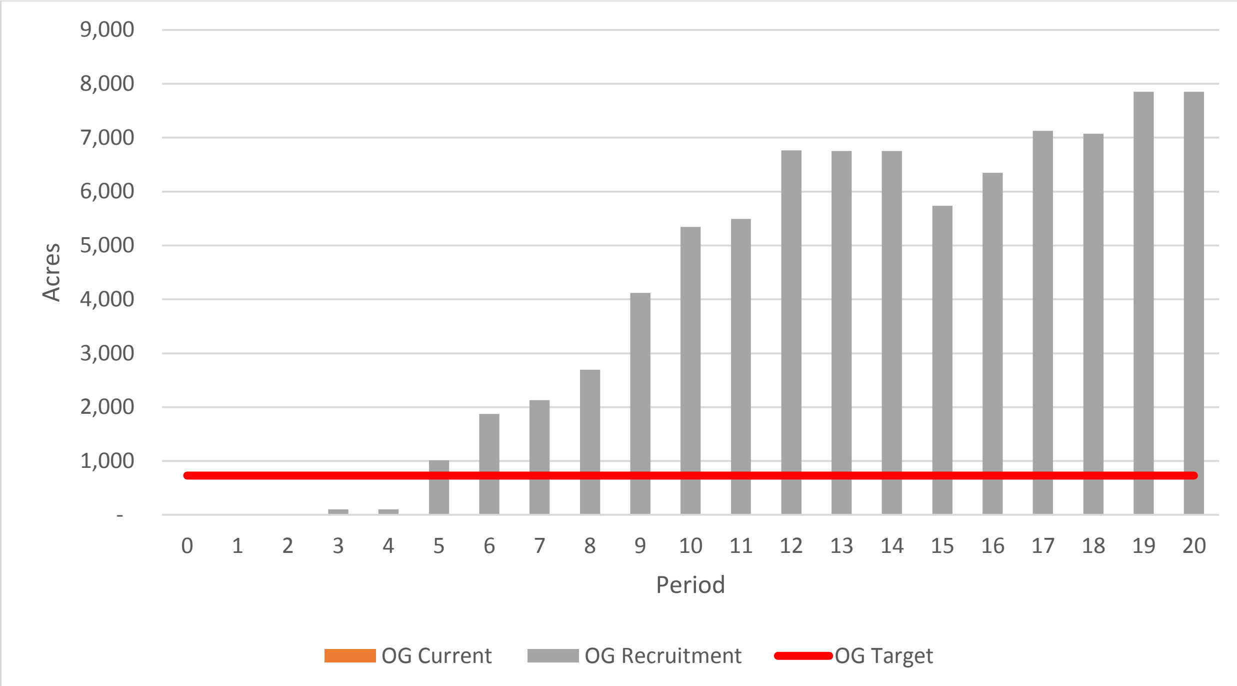


Figure 188: CE Old Growth Acres (Bozeman) – Grizzly Bear Security Zones Constrained

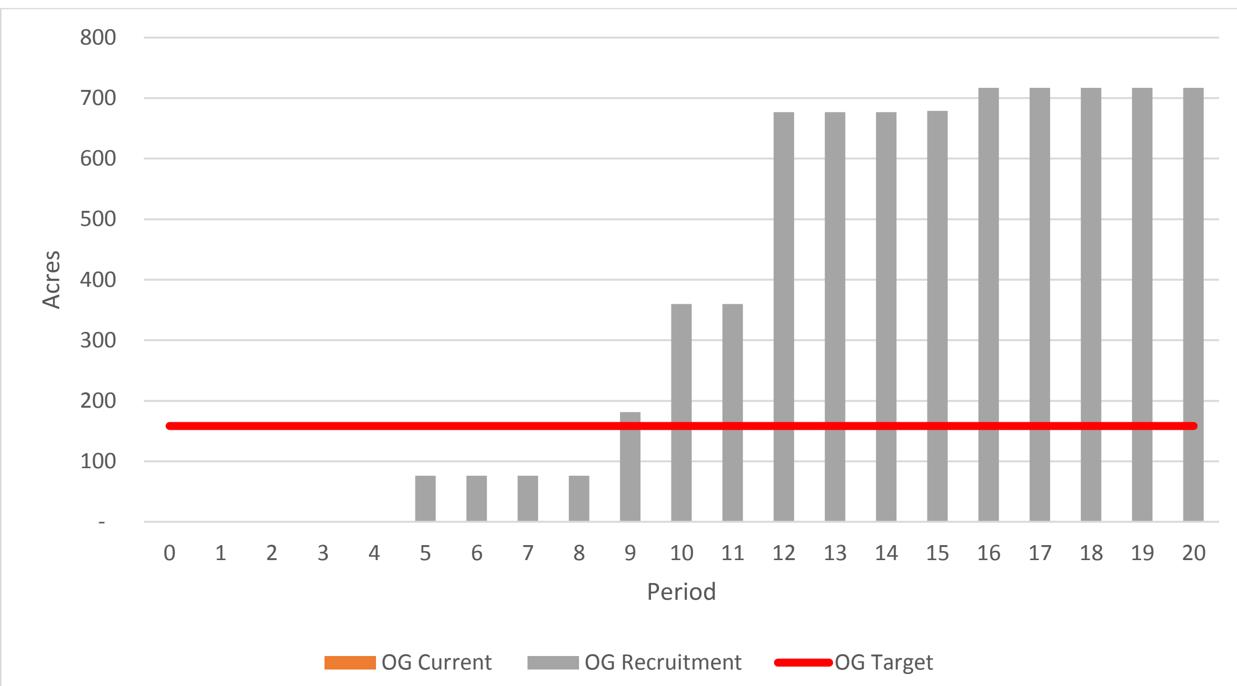


Figure 189: CE Old Growth Acres (Conrad) – Grizzly Bear Security Zones Constrained

Figure 190: CE Old Growth Acres (Dillon) – Grizzly Bear Security Zones Constrained

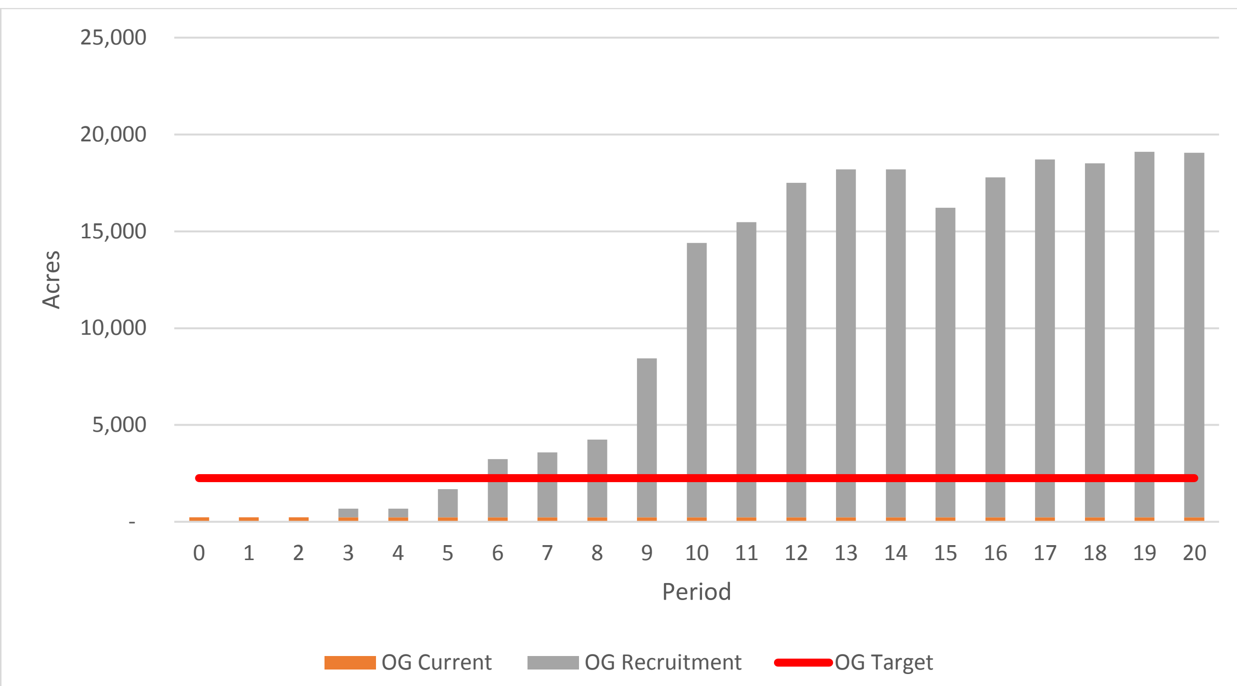


Figure 191: CE Old Growth Acres (Helena) – Grizzly Bear Security Zones Constrained

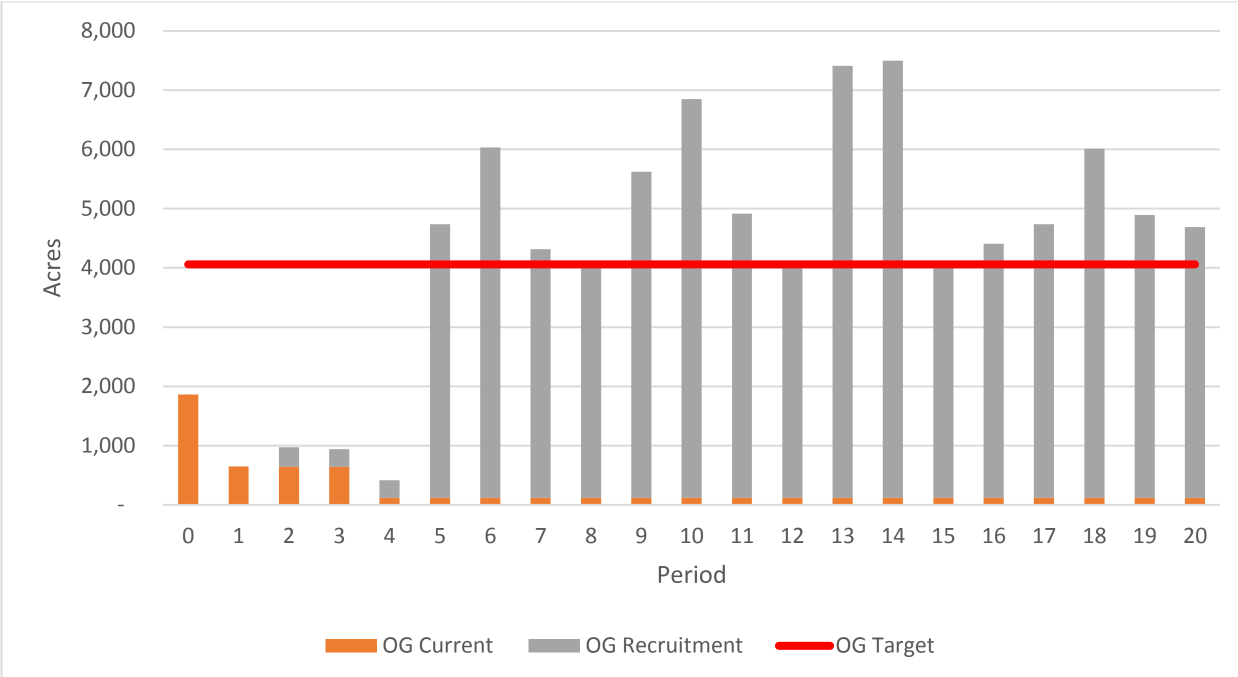


Figure 192: NW Old Growth Acres (Kalispell) – Grizzly Bear Security Zones Constrained

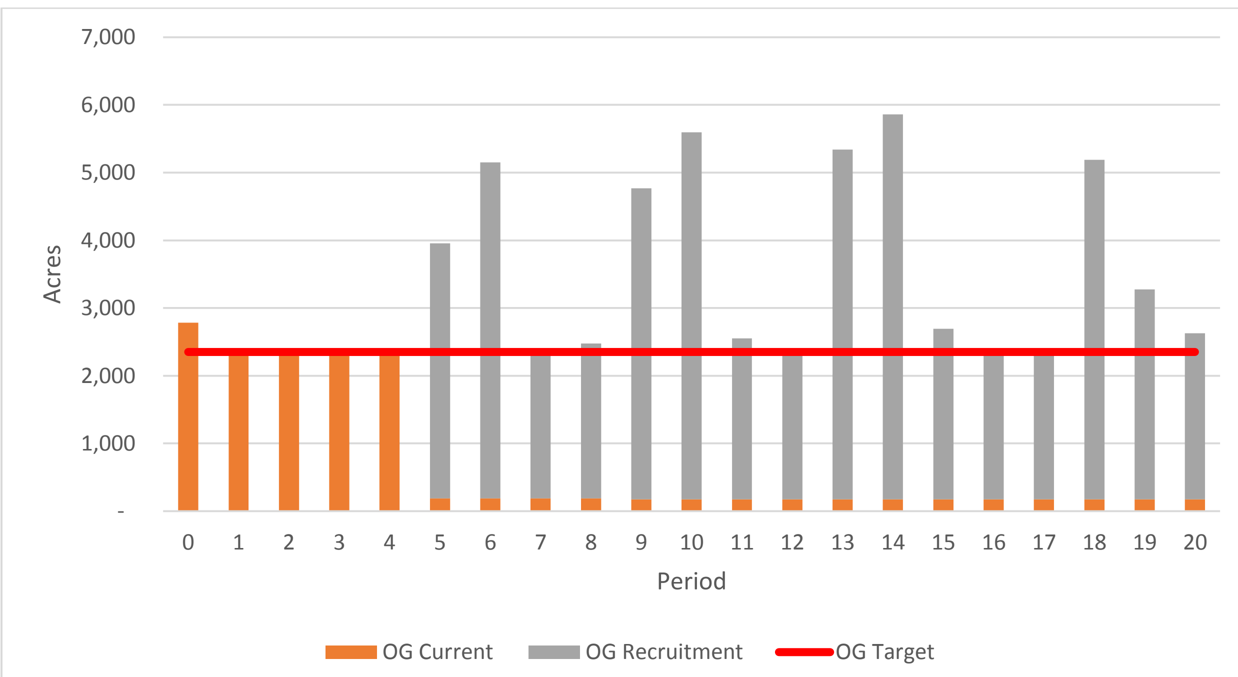


Figure 193: NW Old Growth Acres (Libby) – Grizzly Bear Security Zones Constrained

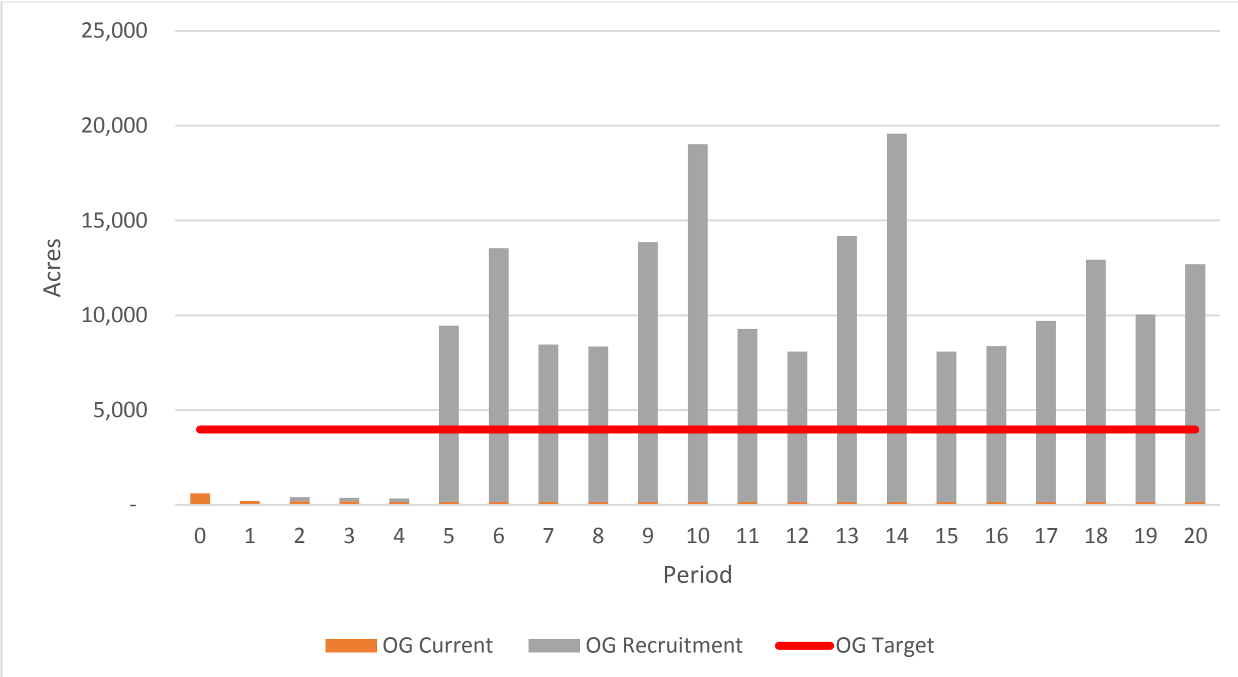


Figure 194: NW Old Growth Acres (Plains) – Grizzly Bear Security Zones Constrained

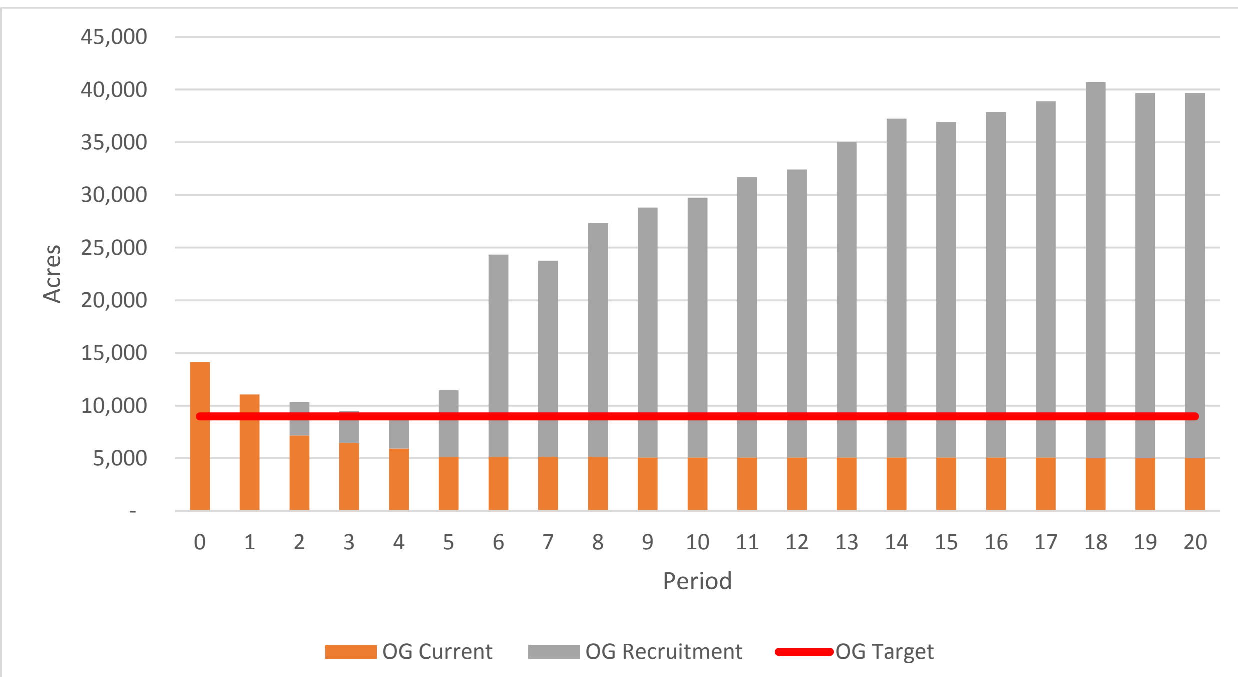


Figure 195: NW Old Growth Acres (Stillwater) – Grizzly Bear Security Zones Constrained

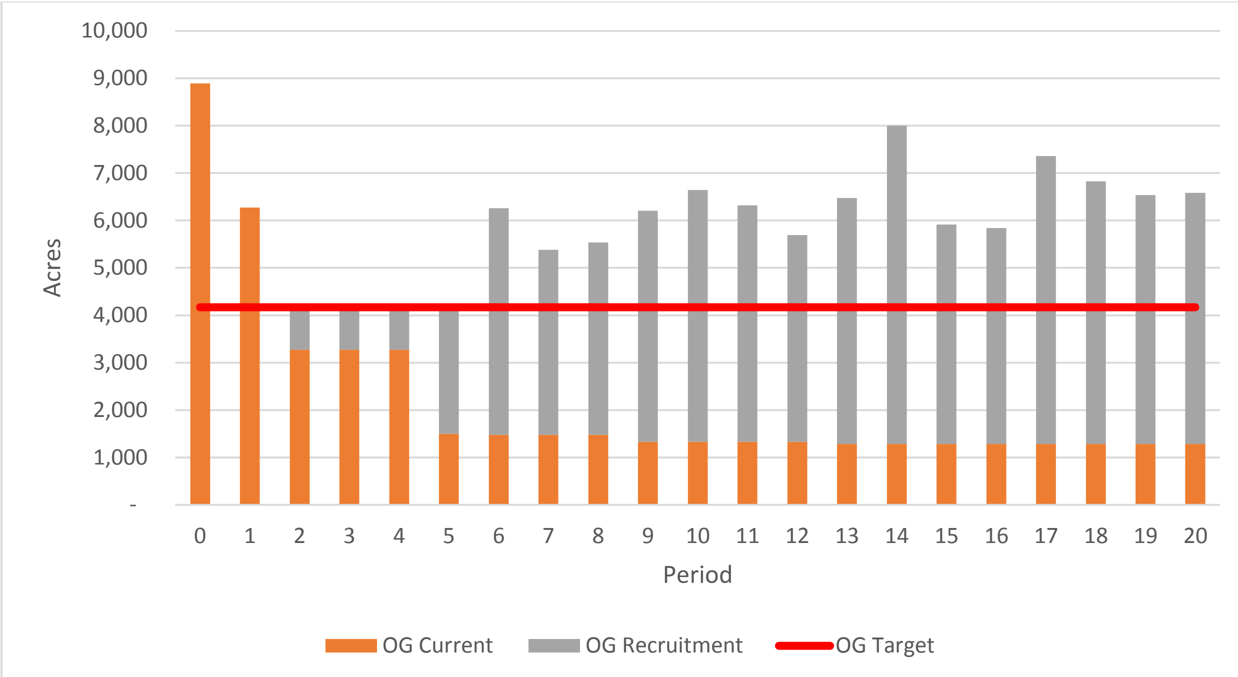


Figure 196: NW Old Growth Acres (Swan) – Grizzly Bear Security Zones Constrained

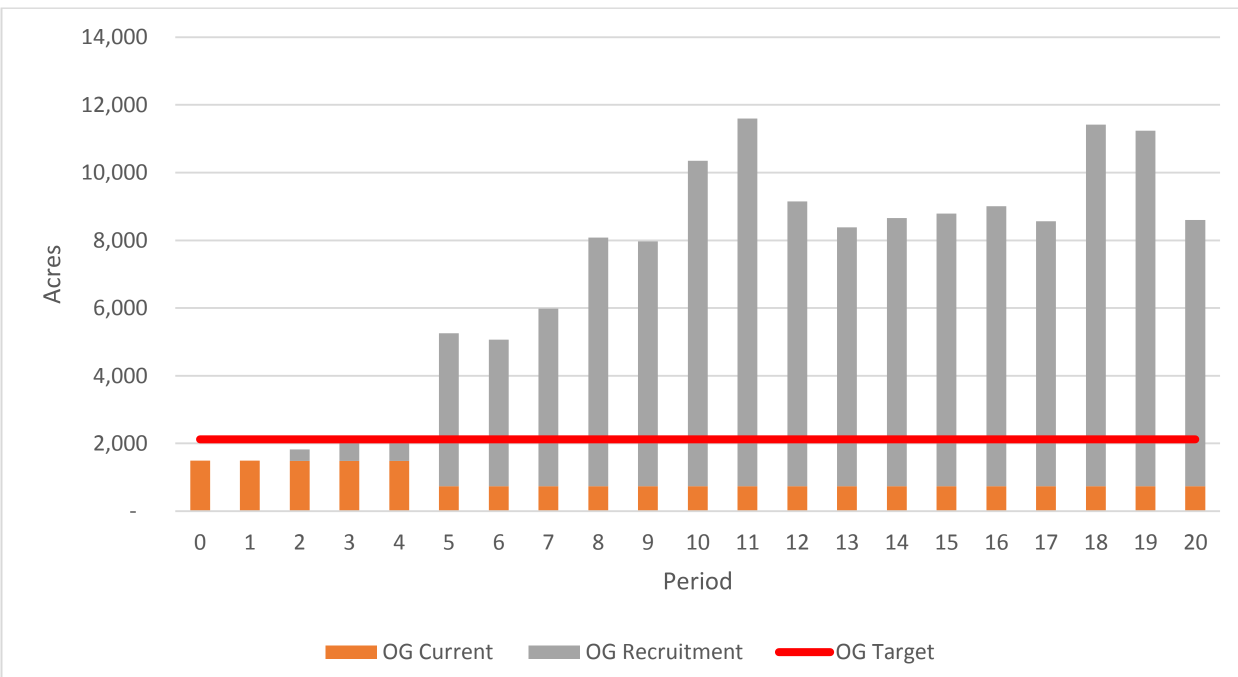


Figure 197: SW Old Growth Acres (Anaconda) – Grizzly Bear Security Zones Constrained

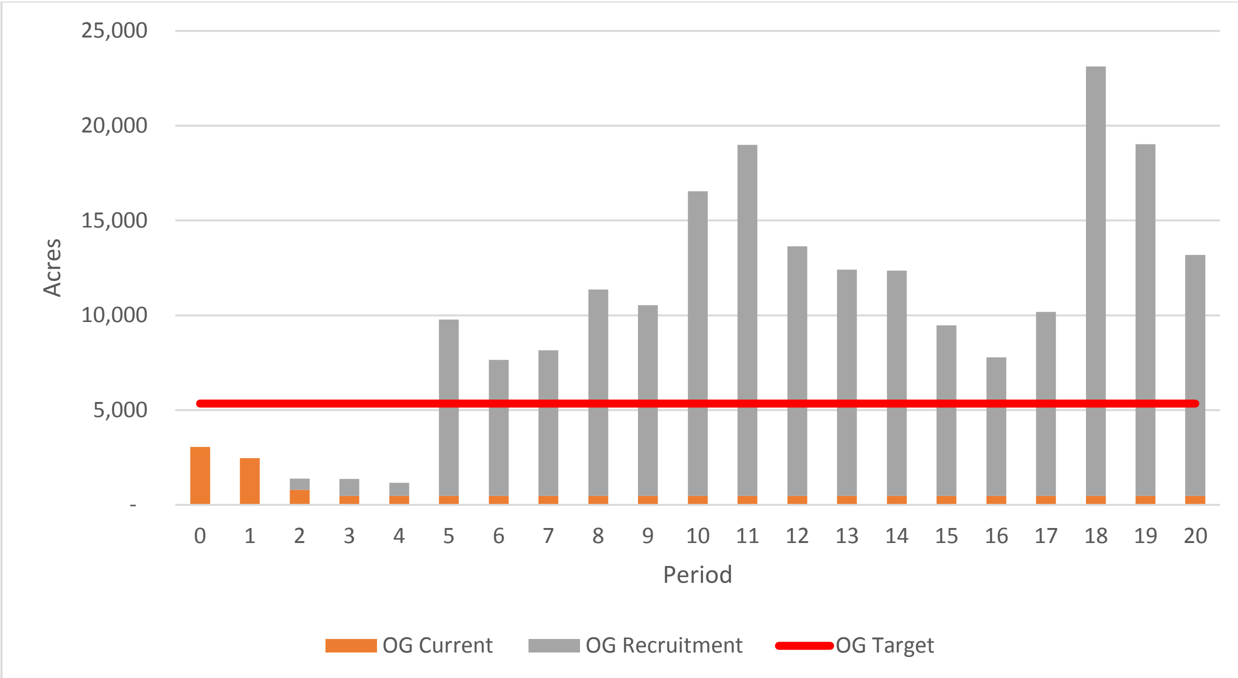


Figure 198: SW Old Growth Acres (Clearwater) – Grizzly Bear Security Zones Constrained

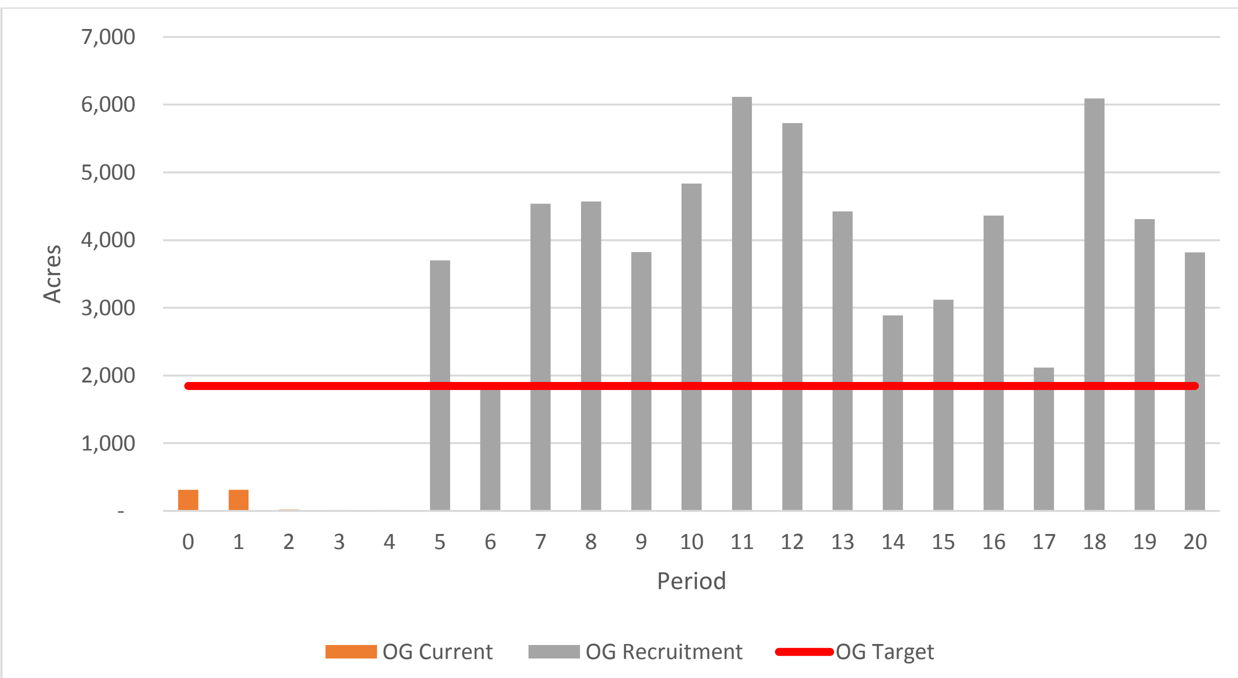


Figure 199: SW Old Growth Acres (Hamilton) – Grizzly Bear Security Zones Constrained

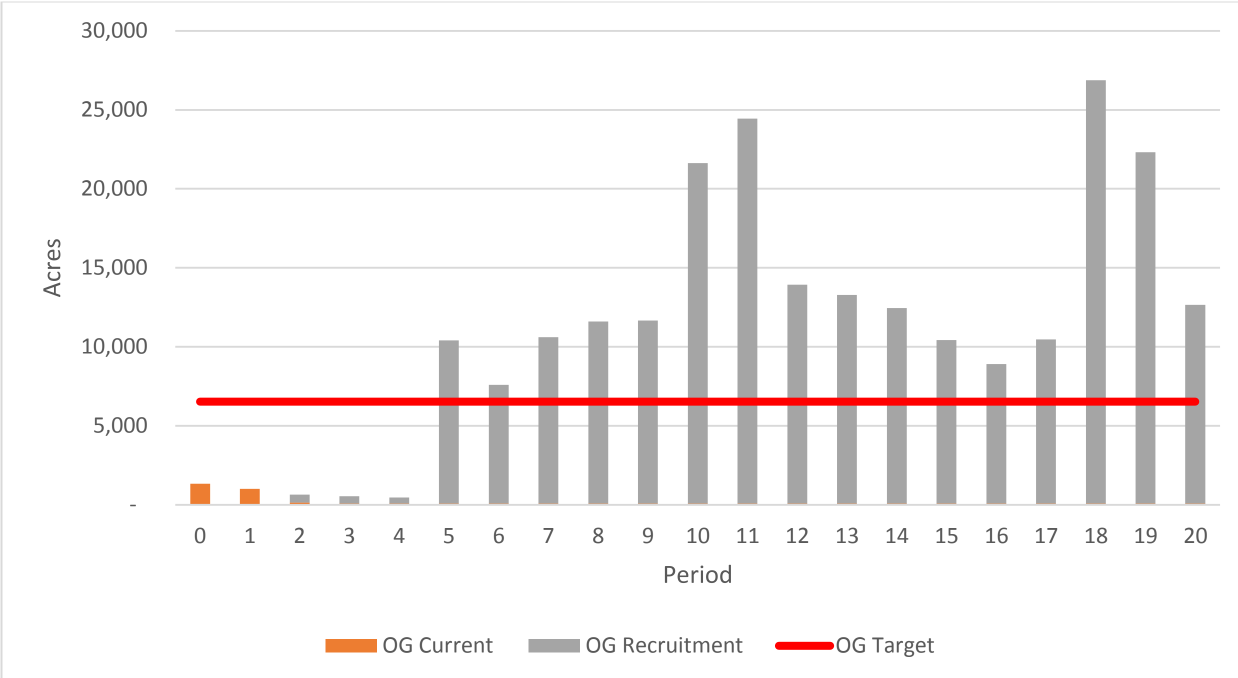


Figure 200: SW Old Growth Acres (Missoula) – Grizzly Bear Security Zones Constrained

21 Appendix N: Silvicultural Regime Acre Constraints

The following table shows the percentage of acres that was allowed to be allocated towards CCRX, STRX, SWRX and UERX for each unique combination of unit and species. These percentages were used by the silvicultural regime constraint in the LP model to set a threshold value for each management pathway type.

Table 32: Silvicultural Regime Constraint Percentages

Species	Regime	Unit: ANA, CLW, HAM, MSO	EA, BOZ, CON, HEL	DIL	KAL, LIB, PLN	STW, SWN
P	CC					
	ST					
	SW	25%	83%	14%	25%	20%
	Uneven	75%	17%	86%	75%	80%
D	CC					
	ST	44%	60%	40%	44%	48%
	SW	11%	15%	10%	11%	12%
	Uneven	45%	25%	50%	45%	40%
DL, L, W4	CC					
	ST	32%	0%	0%	40%	28%
	SW	8%	0%	0%	10%	7%
	UM	60%	0%	0%	50%	65%
LP, W3	CC	100%	100%	100%	100%	100%
	ST					
	SW					
	Uneven					
WP, GF, MC	CC					
	ST	44%	60%	40%	40%	28%
	SW	11%	15%	10%	10%	7%
	Uneven	45%	25%	50%	50%	65%
AF, C, S, WH, W6	CC	16%	5%	10%	16%	17%
	ST	48%	15%	30%	48%	51%
	SW	16%	5%	10%	16%	17%
	Uneven	20%	75%	50%	20%	15%
W1	CC					
	ST					48%
	SW	25%			25%	12%
	Uneven	75%			75%	40%
NS	CC					
	ST		60%	40%	40%	28%
	SW	25%	15%	10%	10%	7%
	Uneven	75%	25%	50%	50%	65%

22 Appendix O: Habitat Type Data

Habitat type was one of the key parameters in calibrating the Forest Vegetation Simulator (FVS) to properly represent growth on DNRC land. Habitat was therefore assigned to each strata by land office, species and productivity class. These assignments are shown in Table 33, while Table 34 contains a definition of each of the habitat number codes.

Table 33: Habitat Type by Land Office, Species and Productivity Class

		Productivity Class		
Land Office	**Species**	**Low**	**Medium**	**High**
CE	AF	690	690	640
CE	D	320	320	280
CE	LP	690	690	640
CE	MC	320	320	640
CE	NS	320	320	640
CE	P	320	320	260
CE	S	690	690	470
EA	D	320	320	320
EA	LP	640	640	640
EA	MC	320	320	320
EA	NS	130	130	130
EA	P	170	170	170
NW	AF	830	670	620
NW	C	530	530	530
NW	D	280	260	520
NW	DL	280	290	520
NW	GF	510	510	520
NW	L	280	290	530
NW	LP	280	690	620
NW	MC	830	670	530
NW	NS	280	260	530
NW	P	280	320	520
NW	S	830	670	620
NW	W1	280	310	510
NW	W3	690	690	530
NW	W4	670	670	620
NW	W6	830	830	830
NW	WH	570	570	570
NW	WP	620	620	530
SW	AF	830	690	670
SW	D	280	260	590

		Productivity Class		
Land Office	Species	Low	Medium	High
SW	DL	280	250	590
SW	GF	520	520	520
SW	L	280	250	590
SW	LP	280	250	590
SW	MC	280	250	590
SW	NS	280	310	670
SW	P	280	310	590
SW	S	830	660	520
SW	W1	280	250	310
SW	W3	690	660	670
SW	W4	690	660	590
SW	W6	830	830	830

Table 34: Habitat Type Definitions

Number Code	Habitat Type	Common Name
130	PIPO/AGSP	Ponderosa Pine/Bluebunch Wheatgrass
170	PIPO/SYAL	Ponderosa Pine/Snowberry
250	PSME/VACA	Douglas-fir/Dwarf Huckleberry
260	PSME/PHMA	Douglas-fir/Ninebark
280	PSME/VAGL	Douglas-fir/Blue Huckleberry
290	PSME/LIBO	Douglas-fir/Twinflower
310	PSME/SYAL	Douglas-fir/Snowberry
320	PSME/CARU	Douglas-fir/Pinegrass
470	PICEA/LIBO	Spruce/Twinflower
510	ABGR/XETE	Grand Fir/Beargrass
520	ABGR/CLUN	Grand Fir/Queencup Beadlily
530	THPL/CLUN	Western Redcedar/Queencup Beadlily
570	TSHE/CLUN	Western Hemlock/Queencup Beadlily
590	ABGR/LIBO	Grand Fir/Twinflower
620	ABLA/CLUN	Subalpine Fir/Queencup Beadlily
640	ABLA/VACA	Subalpine Fir/Dwarf Huckleberry
660	ABLA/LIBO	Subalpine Fir/Twinflower
670	ABLA/MEFE	Subalpine Fir/Menziesia
690	ABLA/XETE	Subalpine Fir/Beargrass
830	ABLA/LUHI	Subalpine Fir/Smooth Wood-Rush

23 Appendix P: Strata Starting Age

Age is difficult to determine stands on DNRC land, since most of them are uneven-aged. It is however crucial to assign an age to each stand, since it is an important element in structuring the management pathway and compiling the linear programming model. Age was therefore assigned to each strata by land office, size class, and productivity class. These assignments are shown in

Table 35: Age by Land Office, Size and Productivity Class

		Productivity Class		
Land Office	**Size**	**Low**	**Medium**	**High**
CE	7	15	15	15
CE	8	65	65	65
CE	9	115	115	115
EA	7	15	15	15
EA	8	55	55	55
EA	9	95	95	95
NW	7	35	25	15
NW	8	65	55	45
NW	9	115	115	115
NW	W1	155	155	155
NW	W3	135	135	115
NW	W4	155	155	155
NW	W6	165	165	165
SW	7	15	15	15
SW	8	55	55	55
SW	9	115	115	115
SW	W1	155	145	145
SW	W3	135	135	135
SW	W4	175	155	155
SW	W6	165	165	165

24 Appendix Q: Wildlife Habitat Constraints

The DNRC has an obligation towards maintaining and creating habitat for various wildlife species through a number of administrative rules. The following section lists the constraints applied or considered, along with the relevant ARMs and HCP commitments, as well as the rationale behind their inclusion or exclusion from the modeling effort.

Table 36: Wildlife Constraints Developed from Forest Management ARM's and DNRC HCP

Species	ARM or HCP Measures	Constraint Description Summary	Related Data Available	Geographic Area Applicable	Notes
Grizzly Bear	HCP, GB-PR6 also east side land offices covered under rule: 36.11.434(1)(d)	Hiding cover in riparian areas -- Apply constraints for riparian harvest strategy. All RMZs associated with class 1 streams deferred.	Stream layer(s) and SLI stand data	All forest lands including both HCP and non-HCP lands	Constraint parameters are those defined for aquatic buffers -- taken out of commercial SLI acres and not included as operable. All Class 1 aquatic buffers deferred. Widths: 120 ft. SWN, STW, LIB; 100 ft. MSLA, KU, CLW, PLNS, HAM; 80 ft. East Side and ANA. Class 2 and 3 -- 25 ft. deferrals with the remaining 25 ft. of the 50 ft. buffer harvested.
Grizzly Bear	HCP, GB-RZ2	100 ft. Visual Screening buffers along open roads -- no clear-cut or seed-tree treatments may occur in these buffers.	Road layer, SLI stand data, recovery zone boundary, and NROH CYE boundary	All Recovery Zone lands and CYE NROH.	No notes
Grizzly Bear	ARM 36.11.432(1)(d)	34,363 commercial acres of Core deferred from harvest.	Grizzly Bear Core polygon layer and SLI stand data	Stillwater Block	No notes

Species	ARM or HCP Measures	Constraint Description Summary	Related Data Available	Geographic Area Applicable	Notes
Canada Lynx	HCP, LY-HB2(2) and ARM 36.11.411	In lynx habitat, retain average of 2 snags and 2 live recruitment tree/acre >21 inches DBH on warm and moist, and wet habitat type groups; and 1 snags and 1 live recruitment tree/acre.	SLI stand data and/or forest stand polygon layer.	All forested state trust lands	Uses constraint approach similar to 2004. Base constraint on expected trees/ac and volume retained in live recruitment trees by prescription applied in model. Constraint applied to green trees given high defect in most large, dead snags that are retained.
Canada Lynx	HCP, LY-HB6	At each Land Office, retain at least 65% total potential class lynx habitat in the suitable habitat condition. Suitable habitat consists of stands in appropriate habitat types that possess at least 40% total canopy closure in sapling, pole and/or saw-timber classes.	Modeled lynx habitat fields in SLI and forest stand polygon layer.	All forested scattered lands outside of lynx LMA's	Because the model could not grow canopy cover for in-growth over time in a manner that would closely reflect reality, a basal area requirement of 50 square feet was used in lieu of the 40% canopy cover requirement.
Canada Lynx	HCP, LY-LM1	At scale of each LMA, retain at least 65% total potential class lynx habitat in the suitable habitat condition. Suitable habitat consists of stands in appropriate habitat types that possess at least 40%	Modeled lynx habitat fields in SLI and forest stand polygon layer, and LMA polygon layer.	Applies to lynx habitat on DNRC lands within lynx LMA's	Because the model could not grow canopy cover for in-growth over time in a manner that would closely reflect reality, a basal area requirement of 50 was used in lieu of the 40% canopy cover requirement.

Species	ARM or HCP Measures	Constraint Description Summary	Related Data Available	Geographic Area Applicable	Notes
		total canopy closure in sapling, pole and/or saw-timber classes.			
Canada Lynx	HCP, LY-LM2	No more than 15% of total potential habitat class may be converted to non-suitable class in each decade.	Modeled lynx habitat fields in SLI and forest stand polygon layer, and LMA polygon layer.	Applies to lynx habitat on DNRC lands within lynx LMA's	Also viewed as a limit on even-aged harvest acres per decade. Once that limit is hit, only uneven-aged regimes can be selected.
Canada Lynx	HCP, LY-LM3(1)	At scale of each LMA, retain at least 20% total potential class lynx habitat in the winter foraging habitat condition. Winter foraging habitat consists of saw-timber stands that possess at least 40% total stand canopy closure and contain AF, SP, and/or GF.	Modeled lynx habitat fields in SLI and forest stand polygon layer, and LMA polygon layer.	Applies to lynx habitat on DNRC lands within lynx LMA's	Because the model could not grow canopy cover for in-growth over time in a manner that would closely reflect reality, a basal area requirement of 60 was used in lieu of the 40% canopy cover requirement.
Canada Lynx	ITP constraint	No more than 1,200 acres of lynx habitat can be pre-commercially thinned annually.	Modeled lynx habitat fields in SLI and forest stand polygon layer, and LMA polygon layer.	Applies to lynx habitat on DNRC lands within lynx LMA's	No notes

Species	ARM or HCP Measures	Constraint Description Summary	Related Data Available	Geographic Area Applicable	Notes
Bald Eagle	36.11.429 (1)(c)(ii) and (d)(ii)	Allow no harvest prescriptions that would result in residual basal areas lower than 60 sq. feet.	Nest tree point locations and SLI data	Buffer out from nest point to 800m on DNRC lands.	This simplified constraint requires a moderate threshold of cover retention across the entire primary use area. This approach "averages" the harvest across the entire 800m buffer area and would take into account required heavy retention in nest site areas, but allows for more volume removal at greater distance from the nest site area.
Snags	36.11.411	Retain average of 2 snags and 2 live recruitment tree/acre >21 inches DBH on warm and moist, and wet habitat type groups; and 1 snags and 1 live recruitment tree/acre.	NA	NA	Uses constraint approach similar to 2004. Base constraint on expected trees/ac and volume retained in live recruitment trees by prescription applied in model. Constraint applied to green trees given high defect in most large, dead snags that are retained.

Table 37: Species and Associated Conservation Measures Not Considered

Species	ARM or HCP Measures	Constraint Description Summary	Related Data Available	Geographic Area Applicable	Notes

Species	ARM or HCP Measures	Constraint Description Summary	Related Data Available	Geographic Area Applicable	Notes
Grizzly Bear	HCP, GB-ST2	19,000 acres of class A lands under 4 year active/8 year rest mgmt.	Class A lands polygon layer and SLI stand data	Stillwater Block	A constraint for this requirement was not applied in 2015 or 2004. The SYC team discussed the need for a constraint to address HCP, GB-ST2 and concluded that given the presence of interspersed deferred acres in these zones and ability to manage in commercial 4-year windows, no constraint was necessary.
Grizzly Bear	ARM 36.11.431(1)(a)	55,000 of grizzly bear management units under 3 year active/6 year rest mgmt.	Grizzly bear subunit polygon layer and SLI stand data	Swan River State Forest	Did not include a constraint for this in 2015 or 2004. The SYC team discussed the need for a constraint to address this ARM and concluded that given the ability to manage in commercial 3-year windows and winter period, no constraint was necessary.

Species	ARM or HCP Measures	Constraint Description Summary	Related Data Available	Geographic Area Applicable	Notes
Grizzly Bear	HCP, GB-SC2	33,300 acres of scattered parcels in recovery zones and CYE NROH under 4 year active/8 year rest mgmt.	Scattered parcels recovery zone layer, CYE NROH, and SLI stand data	All HCP scattered lands in recovery zones and CYE NROH	The SYC team discussed the need for a constraint to address HCP, GB-SC2 and concluded that given the ability to manage in commercial 4-year windows and winter period, no constraint was necessary. The smaller geographic area of "a parcel" compared to a larger subunit makes it inherently less necessary to revisit a section within an 8 year rest window.
Canada Lynx	HCP, LY-HB5 and Fisher ARM 36.11.440(c)	Provide for habitat connectivity of mature forest cover across 3rd order drainages.	DEM, SLI stand data, forest stand polygon layer.	Ridgetops associated with DNRC forest land.	Considerable subjective analysis would be required for a minimal number of acres constrained. The team concluded that this measure typically would be met in deferrals, RMZs, and through application of allowable prescription percentages by cover type.

Species	ARM or HCP Measures	Constraint Description Summary	Related Data Available	Geographic Area Applicable	Notes
Canada Lynx	HCP, LY-LM3(2)	For any treated PCT stand in lynx habitat in LMAs, retain 20% of each project area (i.e., total of all PCT units identified for treatment) in an un-thinned condition until they meet saw-timber size class.	Modeled lynx habitat fields in SLI and forest stand polygon layer, and LMA polygon layer.	Applies to lynx habitat on DNRC lands within lynx LMA's	This constraint was deemed unnecessary given that annual budgetary constraints have a predominant functional limit on thinning in DNRC's program. Also, PCT would be allowed unconstrained on all non-lynx forest types, and the minor acreages of retained patches were deemed to have minimal influence on long-term yield.
Fisher	36.11.440	Apply constraints for riparian harvest strategy, old growth, and snags to cover this species. All RMZs associated with class 1 streams deferred.	NA	NA	Addressed through coarse filter management and general application of allowable harvest regimes, riparian harvest strategies, and snag requirements. No additional specific constraint required.
Flammulated Owl	36.11.437	No Constraint Necessary	NA	NA	Addressed through coarse filter management, old growth, and general application of allowable harvest regimes and snag requirements.

Species	ARM or HCP Measures	Constraint Description Summary	Related Data Available	Geographic Area Applicable	Notes
Black-Backed Woodpecker	36.11.438	No Constraint Necessary	NA	NA	Addressed through coarse filter management and general application of allowable harvest regimes. The measure is typically met by retaining desirable live and dead trees in burned areas and intensively burned acreages on inoperable or deferred ground.
Pileated Woodpecker	36.11.439	No Constraint Necessary	NA	NA	Addressed through coarse filter management, old growth, and general application of allowable harvest prescriptions by cover type and snag requirements.
Common Loon	36.11.441	No Constraint Necessary	NA	NA	Harvest-related mitigation requirements are rare and affect a very small number of acres annually on average (i.e., <50 ac per yr.).
Peregrine Falcon	36.11.442	No Constraint Necessary	NA	NA	Harvest-related mitigation requirements are rare and affect a very small number of acres annually on average (i.e., <50 ac per yr.).

Species	ARM or HCP Measures	Constraint Description Summary	Related Data Available	Geographic Area Applicable	Notes
Gray Wolf	36.11.430	No Constraint Necessary	NA	NA	No specific forest cover requirements for this species.
Wolverine	n/a	No Constraint Necessary	NA	NA	No specific forest cover requirements for this species, and most limiting habitat areas are relatively non-forested, high elevation zones with persistent snow late into spring.
Yellow-Billed Cuckoo	n/a	No Constraint Necessary	NA	NA	Suitable habitat for this species in Montana is comprised of cottonwood river bottoms where active timber harvest is not economical and is generally prohibited.
Big Game	36.11.443	No Constraint Necessary	NA	NA	Addressed through coarse filter management and general application of allowable harvest prescriptions by cover type.

25 Appendix R: Growth Rates by Land Office

In this section, the estimated growth rates in board feet per acre per year determined by the calculation are displayed for each Land Office Growth rates from other published sources are also included for purposes of comparison.

Table 38: Estimated and Historic Growth Rates (bf/ac/yr)

Area	2015 SYC Grow Only	2015 SYC Bio Gross	2014 FIA[28]	1989 FIA[29]	Timber Resources Publications[30]
Statewide	111	111	72	126	111
NW	159	171	129	151	146
SW	112	119	51	148	97
CE	54	54	10	53	97
EA	48	32	60	90	69

[28] Figures shown are for growing stock on State and Local Government ownership; data queried from USFS Forest Inventory and Analysis (FIA), Forest Inventory Data Online (FIDO)

[29] Figures shown are for growing stock on State and Local Government ownership; data queried from USFS Forest Inventory and Analysis (FIA), Forest Inventory Data Online (FIDO)

[30] Figures shown are average annual net growth per acre for State/Other Public ownership reported in the following publications: NW—Timber Resources of Lincoln, Sanders, Flathead, and Lake Counties, Montana Dept. of State Lands, Forestry Division, and Forest Survey, Intermountain Forest and Range Experiment Station, Region 1, USDA Forest Service, 1982; SW—Timber Resources of Mineral, Missoula, and Ravalli Counties, Montana Dept. of State Lands, Forestry Division and Forest Survey, Intermountain Forest and Range Experiment Station, Region 1, USDA Forest Service, 1983; CE—Timber Resources of the Headwater Counties, Montana Dept. of State Lands, Forestry Division and Forest Survey, Intermountain Forest and Range Experiment Station, Region 1, USDA Forest Service, 1984; EA—Timber Resources of Eastern Montana, Montana Dept. of State Lands, Forestry Division and Forest Survey, Intermountain Forest and Range Experiment Station, Region 1, USDA Forest Service, 1984.

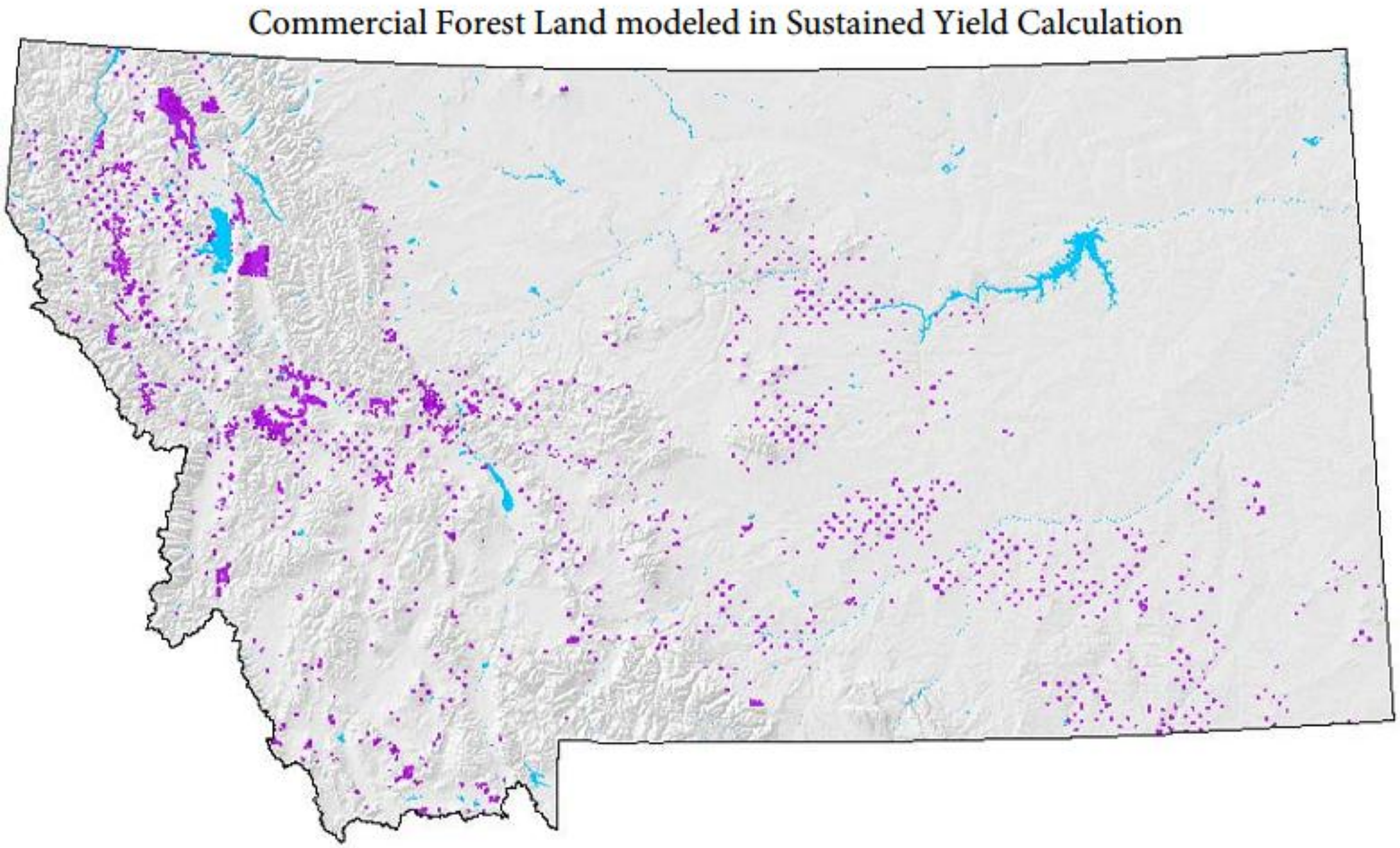


Figure 201: Location of Commercial Forest Acres Included in the Calculation